APPENDIX H

STANDARD OPERATING PROCEDURES

ONLY THE FOLLOWING STANDARD OPERATING PROCECURES ARE RELEVANT TO THIS DOCUMENT AND INCLUDED IN THIS APPENDIX:

SAS-01-01
SAS-01-02
SAS-02-01
SAS-02-02
SAS-03-01
SAS-03-02
SAS-03-03
SAS-04-03
SAS-04-04
SAS-05-01
SAS-05-02
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SAS-05-04
SAS-05-05
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SAS-11-06

STANDARD OPERATING PROCEDURE
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SOP SERIES SAS-01

FILE AND DATA MANAGEMENT

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STANDARD OPERATING PROCEDURE
NO. SAS-01-01

FIELD ACTIVITY DOCUMENTATION
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes procedures for documenting field activities and guidance on types and specificity of data to be recorded. Procedures are included for documentation on field logbooks, field forms, and/or field electronic data recorders. This standard is also applicable to photographic documentation collected to support field observations of site conditions and field data entries.

2.0 EQUIPMENT AND MATERIALS

- Field logbooks;
- Field forms;
- Camera and/or camcorder; and
- Waterproof pens with non-erasable ink.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 FORMAT

4.1 FIELD LOGBOOK

Field logbooks shall be bound books that are permanently assigned to a specific project. The cover of each logbook will provide the following identifying information:

- Name of project/site;
- Project number; and
- Book number.

The consultant's contact person(s), address and phone number should be recorded on the inside cover of the field logbook. Only field logbooks with pre-numbered pages shall be used and no pages shall be removed from the logbook.

4.2 Field Forms

Field recording forms are also used for data collection in a variety of activities. The forms include logs for boreholes, well construction, well sampling, etc. It is not necessary to duplicate information recorded on field forms into the field logbooks.

5.0 ENTRIES

5.1 Daily Entries

At the beginning of each daily entry, the following information is recorded:

- Date;
- Time of arrival at the site;
- Weather conditions;
- Physical/environmental conditions at the field site;
- Field personnel present and their responsibilities;
- Level of personal protection if other than Level D; and
- Signature of the person making the entry.

For investigation activities, the entry for each day will contain a complete record of the day's activities including, but not limited to, the following information, unless the data is recorded on field forms.

- Names and titles of site visitors;
- Information concerning sampling changes, scheduling modifications and change orders.
- Location, description and log of photographs of sampling points;
- Description of reference points for maps and photographs of sampling site;
- Field observations;
- Field measurements;
- Equipment calibration and maintenance;
- Sample identification numbers;
- Name of laboratory and overnight delivery service provider or name of laboratory courier and time of sample pick-up;
- Sample documentation, such as chain-of-custody form numbers and shipment air bill numbers;
- Decontamination procedures used;
- Documentation for investigation-derived wastes, such as contents and approximate waste volume in each drum, and number of drums generated;
- Time of departure from the site; and
- Signature of person responsible for observations and date.

Field logbooks are also used as a daily record for remediation activities. General entries similar to the ones listed above are used in remediation activity logbooks. In addition, daily entries regarding excavation activities, waste disposal quantities and methods of transport, system performance data from any remediation systems (e.g. soil vapor extraction systems, recovery well systems, etc.), system or equipment calibration or maintenance performed, and any other pertinent information regarding daily activities.

All logbook entries shall be printed legibly using a pen with waterproof, non-erasable ink. Any lines or pages inadvertently left blank will have a single line drawn through them with the logging person's initials and date written on the line.

When a field log form is used to record field data, all form fields will be completed in full on a daily basis. If a specific data entry area is not applicable, it will be clearly marked as such with the use of "NA" or a dashed line drawn through it. A single line will be drawn through any unused data entry areas on the form with the field person's signature on the line.

5.2 Entry Changes

Entry changes should be avoided by carefully entering data in the logbook. If a change is required, it should be made by drawing a single line through the original entry such that the original entry is not obscured and entering the correct information next to the original entry. The change in entry will be initialed and dated by the logger. Only the person making the entry may change it.

If there is a change in the person recording field notes during a particular day, that person shall be identified in the logbook prior to making entries. The new logger shall sign and date the logbook at the beginning and end of his entry.

6.0 FORM AND LOGBOOK MANAGEMENT

Site-specific field logbooks and forms will be kept in the in-office project file when not in use. If forms or logbooks are used in the field for an extended period of time, copies of used pages will be made, delivered to the office, and filed in the project file on a periodic basis.

7.0 PHOTOGRAPHIC AND VIDEO RECORDS

7.1 Photographic Record

Photographs shall be taken in the field on a daily basis to document field activities. Field log entries for each photograph may include:

- Photographer’s name;
- Project name and project number;
- Roll and frame number, or digital photograph number;
- Date and time;
- Description of photograph including sampling point, sample name, depth and other relevant identifying information, such as direction faced (e.g. “looking south”) and relationship of photograph to site features.

Photograph prints and negatives will be stored in the project file. Digital photographs will be stored in the electronic project file. If digital photographs are downloaded from the camera in the field, they will be transferred to the in-office electronic file on a regular basis. Photographic prints or paper copies of digital images will be identified with recorded field book entry information.

7.2 Video

Video site recordings will be logged in the field logbook with the following information:

- Recorder's name;
- Project name and project number;
- Date and time;
- Description of subject of video including identification of any persons appearing in video.

If video does not have accompanying audio, record a placard of the site name, date and time and subject of video at the beginning of the video. If the video recorder has an audio recording feature, a narration of the video identifying information may be used. The video tape or digital video disk (DVD) will be labeled with the project name, project number, date, location, and subject). The original, unaltered tape shall be placed in the official files.

8.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D0420-98R03 Guide to Site Characterization for Engineering Design and Construction Purposes.

ASTM International, D4840-99R04 Guide for Sample Chain-of-Custody Procedures.

ASTM International, D5434-03 Guide for Field Logging of Subsurface Explorations of Soil and Rock.

ASTM International, D6089-97R03E01 Guide for Documenting a Ground-Water Sampling Event.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE NO. SAS-01-02

PROJECT FILE MANAGEMENT Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines to assure the integrity and preservation of electronic files within the Network. It also describes the manner in which electronic files are to be identified and handled in the routine entry of data, reports, proposals, etc. onto computer hard drives and tapes.

2.0 EQUIPMENT AND MATERIALS

- Project files including, but not limited to, documents, data, photographs, correspondence and maps.
- Appropriate paper document storage supplies, furniture and facilities.
- Permanent electronic file storage equipment (computer hard drives and random access memory computer disks [CD-ROMs]).

3.0 FILE SECURITY

Adequate security will be maintained for both paper and electronic files relating to each project in accordance with its corporate document security policies.

4.0 PAPER FILES

4.1 ACTIVE PROJECTS

Paper files containing documents relating to an active project will be maintained at the consultant's office. All paper files will be sorted according to type and filed in accordance with the consultant's internal project-specific paper filing system. Paper documents from field activities will be brought from the field to the consultant's office for filing on a regular basis. All paper documents will be maintained in the active project files until final closure of the project.

4.2 CLOSED PROJECTS

Upon final closure of the project, all paper files containing documents relating to the project will be permanently archived in accordance with the consultant's internal file retention policies and client-specified file retention or archiving requirements. Discuss these procedures with the Project Manager.

5.0 ELECTRONIC FILES

5.1 ACTIVE PROJECTS

Electronic files containing documents relating to active project will be maintained at the consultant's office. All electronic files will be sorted according to type and filed in accordance with the consultant's internal electronic project filing system. Data saved electronically to field computers will be transferred to the consultant's in-office computer network on a regular basis via CD-ROMs or as attachments to electronic mail (email) transmissions. All electronic documents will be maintained in the active project files until final closure of the project.

5.2 CLOSED PROJECTS

Upon final closure of the project, all electronic files containing documents relating to the project will be permanently archived in accordance with the consultant's internal file retention policies and client-specified file retention or archiving requirements.

5.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-02

FIELD MEASUREMENTS - GENERAL

Author:	**T. Gilles**	**Q2R & Approval By:**	**J. Gonzalez**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE
NO. SAS-02-01

EQUIPMENT CALIBRATION, OPERATION, AND MAINTENANCE
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for controls, calibration, and maintenance of measurement and testing equipment to be used for obtaining samples for chemical analyses, for measuring field parameters, and for testing various parameter/characteristics. The purpose of this SOP is to ensure the validity of field measurement data generated during field activities as required in the Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Measurement and testing equipment ;
- Equipment/instrumentation-specific operation manuals;
- Equipment/instrumentation-specific cases, battery chargers, and attachments; and
- Calibration standards (e.g. standard gas(es), calibration fluids, pH standards, etc.).

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General

Field measurements are used to verify sampling procedures, assist in sample selection, and evaluate field conditions. A variety of equipment/instrumentation may be utilized to obtain the field measurements required to satisfy and document project goals outlined in Work Plans or otherwise specified. Therefore, instrument operators must be thoroughly familiar with the operation of measuring instruments. Users will complete the appropriate training and be certified, if required, before using the instrument in the field.

All equipment/instrumentation will be uniquely and permanently identified (model/serial number, equipment inventory number, etc.). Manufacturer's guides/operation manuals will be kept with the instrument or a designated area on the Site, as appropriate. The Site Manager or designee will obtain, identify, and control all equipment/instrumentation to be used during the project.

4.2 Calibration

Measuring equipment/instrumentation must be calibrated before initial use as recommended in the manufacturer's guide/operation manual. Equipment/instrumentation shall be re-calibrated following 1) the manufacturer's recommended calibration frequency, 2) long periods between uses, 3) readings observed above or below the range of the instrument, and/or 4) signs or evidence of equipment malfunction. Daily calibration and re-calibration activities will be recorded in the field logbook and/or on the appropriate field form and will include the following information:

- Date and time of calibration or re-calibration;
- Equipment/instrumentation manufacturer, make, and model;
- Equipment/instrumentation serial or unique inventory number;
- Method of calibration (may reference procedures outlined in the guide/instrument manual);
- Calibration standard(s) used; and
- Deviations, if any, from the manufacturer's recommended procedure(s) or calibration frequency.

4.3 Operation

Manufacturer's instructions will be followed for correct method(s) of operation. Equipment malfunctions and deviations, if any, from the manufacturer's recommended method(s) of operation will be documented in the field logbook and/or on the appropriate field form. Readings obtained from each instrument shall be recorded in the field logbook or on the appropriate field form.

4.4 Maintenance

Equipment/instrumentation will be maintained in accordance with the manufacturer's recommendations. Equipment/instrumentation that malfunctions or is scheduled for routine maintenance will be clearly labeled to prevent its continued use until repairs/maintenance is completed. The Site Manager or her/his designee will be responsible for ensuring that malfunctioning equipment is identified, marked for repair, repaired either in-house or by an outside company in accordance with manufacturer guidelines, checked following repair, and returned to service. The Site Manager or her/his designee will maintain an equipment log, which contains the following:

- Equipment/instrumentation manufacturer, make, and model;
- Equipment/instrumentation serial or unique inventory number;
- Recommended calibration frequency;
- Recommended maintenance frequency, as appropriate;
- Status (in service, not in use, or out of service for repair/maintenance);
- Dates of status changes (e.g. date returned to service); and
- Inspection and maintenance/repair dates.

5.0 REFERENCE

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001

Author:	T. Gilles	Q2R & Approval By:	J. Gonzalez	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-02-02

SURVEYING
Revision 0

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for surveying activities that will be performed by the consultant. Timeframes or budgets may not always allow for surveying by licensed surveying professionals. The consultant may need to obtain information in a timely and cost effective manner that will aid in project decisions (e.g. groundwater flow direction, hydraulic gradient, etc.). In these cases, the consultant will perform basic surveying to obtain this information. The purpose of this SOP is to outline general procedures to obtain reliable surveying data in support of project goals and decisions as required in the Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Topcon Auto Level or equivalent;
- Tripod;
- Plumb line;
- Graduated surveying stick; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General

Survey equipment shall be inspected prior to commence of surveying activities to ensure that all components are present and functional. Graduations on the surveying stick should be well marked. Equipment not in satisfactory condition should be removed from service and repaired or replaced, as appropriate.

Operators must be thoroughly familiar with the operation of surveying equipment. Operators should complete the appropriate training and be certified, if required, before using the equipment in the field.

4.2 Benchmark Selection

A fixed, permanent reference point is critical for tying in surveying results to known site features and reproducing surveying results in the field. The benchmark should be a unique location, preferable one that would appear on a plat of survey, that is not likely have its elevation affected by field or outside activities (e.g. flange bolt on a fire hydrant, base of a property boundary stake, corner of a loading dock, etc.). The benchmark shall be documented and clearly described in the field logbook and/or on the appropriate field form. The location of the benchmark should also be measured relative to a minimum of two other permanent site features. These measurements should also be recorded in the field logbook and/or on the appropriate field form. Typically, a licensed surveyor will establish the benchmark which will be used on the site. If the benchmark cannot be established by a licensed surveyor, make sure the Project Manager is informed.

4.3 General Procedures

Surveying will be conducted following the procedures outlined below:

1. Make a table in the field logbook or utilized the appropriate field form to record the following information:
    a. Benchmark;
    b. Assigned benchmark elevation;

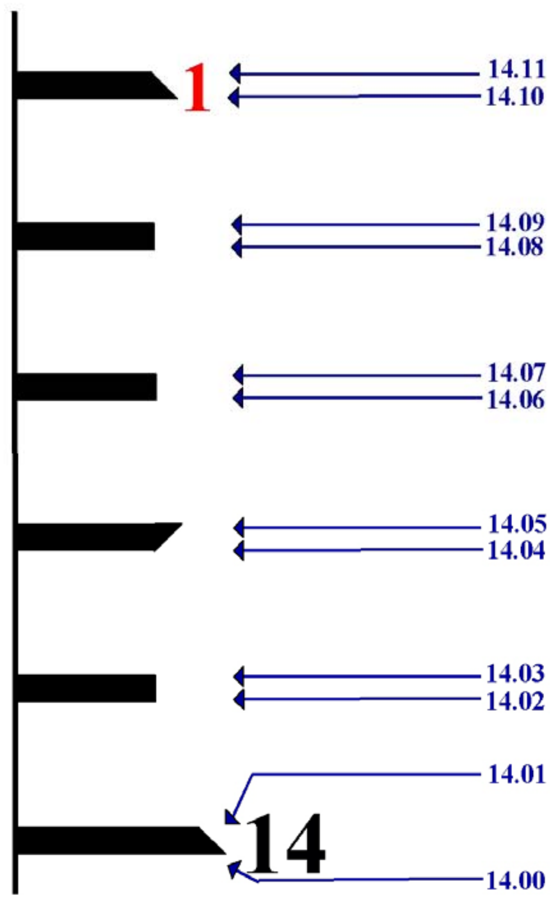
   c. Instrument Height(s);
   d. Temporary Benchmark(s);
   e. Survey points (e.g. monitoring well top of casing, ground surface, etc.); and
   f. Surveying stick graduation.

2. Locate a benchmark (BM).
3. Describe the BM in the field logbook and/or on the appropriate field form. The description must be detailed enough to allow a person unfamiliar with the Site to locate the BM.
4. Measure the location of the BM from at least two other permanent site features and record the measurements in the field logbook and/or on the appropriate field form.
5. Choose a location for the tripod that is in view of the benchmark and as many surveying points as possible.
6. Set up the tripod and attach the plumb line.
7. Adjust the tripod legs until the plumb line hangs at a 90-degree angle from the top plate of the tripod.
8. Place the Topcon Auto Level (or equivalent) on the tripod.
9. Adjust the auto level legs until the Topcon Auto Level is level as indicated by the leveling bubble (Note: The bubble should be centered in the circle).
10. Verify the auto level is level by rotating the auto level 90, 180, and 270-degrees. The bubble should be centered in the circle at all three positions. If the bubble is not centered in the circle, repeat Steps 7 through 10.
11. The surveying assistant will stand the surveying stick on the benchmark.
12. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level electronically or in the field logbook and/or on the appropriate field form as the back sight measurement.
13. The operator shall record Instrument Height #1 (IH_1), which is obtained by adding the surveying stick graduation to the arbitrary benchmark elevation (usually 100.00 feet), in the field logbook and/or on the appropriate field form.
14. The surveying assistant will stand the surveying stick on a surveying point.

15. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the appropriate field form as the front sight measurement.
16. The operator shall record Survey Point #1 (SP_1) elevation, which is obtained by subtracting the surveying stick graduation from IH_1, electronically or in the field logbook and/or on the appropriate field form.
17. Repeat Steps 14 through 16 until all survey points or all survey points visible from the first instrument location have been measured.
18. Locate a Temporary Benchmark (TBM_1).
19. The surveying assistant will stand the surveying stick on TBM_1.
20. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
21. The operator shall record TBM_1 elevation, which is obtained by subtracting the surveying stick graduation from IH_1, electronically or in the field logbook and/or on the appropriate field form.
22. The operator shall relocate the instrument and repeats Steps 6 through 10. Note: During this time the surveying assistant should not remove the surveying stick from the top of TBM_1.
23. Once the instrument has been relocated and leveled, the operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the back sight measurement.
24. The operator shall record Instrument Height #2 (IH_2), which is obtained by adding the surveying stick graduation to the TBM_1 elevation determined in Step 21, electronically or in the field logbook and/or on the appropriate field form.
25. If all surveying points have been measured, skip to Step 36. If all surveying points have not been measured, proceed to step 26.
26. Repeat Steps 14 through 16 until all survey points or all survey points visible from the instrument location have been measured.
27. Locate another Temporary Benchmark ($TBM_{\#}$).
28. The surveying assistant will stand the surveying stick on $TBM_{\#}$.

29. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
30. The operator shall record $TBM_{\#}$ elevation, which is obtained by subtracting the surveying stick graduation from $IH_{\#}$, electronically or in the field logbook and/or on the appropriate field form.
31. The operator shall relocate the instrument and repeats Steps 6 through 10. Note: During this time the surveying assistant should not remove the surveying stick from the top of $TBM_{\#}$.
32. Once the instrument has been relocated and leveled, the operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level electronically or in the field logbook and/or on the appropriate field form as the back sight measurement.
33. The operator shall record Instrument Height # ($IH_{\#}$), which is obtained by adding the surveying stick graduation to the $TBM_{\#}$ elevation determined in Step 30, electronically or in the field logbook and/or on the appropriate field form.
34. Repeat Steps 14 through 16 until all survey points or all survey points visible from the instrument location have been measured.
35. If all surveying points have been measured, skip to Step 36. If all surveying points have not been measured, proceed to step 27.
36. The surveying assistant will stand the surveying stick on the benchmark.
37. The operator should view the surveying stick through the Topcon Auto Level (or equivalent), read and record the surveying stick graduation that intercepts the center crosshairs of the auto level in the field logbook and/or on the surveying data form as the front sight measurement.
38. The operator record BM elevation, which is obtained by subtracting the surveying stick graduation from $IH_{\#}$, electronically or in the field logbook and/or on the appropriate field form.
39. If the BM elevation is within 02/100 of an inch ($\pm$0.02) of the initial or assigned BM elevation, the surveying has been completed successfully. If the BM elevation is not within 02/100 of an inch ($\pm$ 0.02) of the initial or assigned BM elevation, an error was made or the tripod and/or auto level were bumped during surveying. In this case, the surveying activities were not completed successfully and must be repeated.

4.4 Reading the Surveying Stick



5.0 REFERENCE

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001

SOP SERIES SAS-03

SAMPLE COLLECTION - GENERAL

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STANDARD OPERATING PROCEDURE
NO. SAS-03-01

SAMPLE IDENTIFICATION, LABELING, DOCUMENTATION AND PACKING FOR TRANSPORT
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes procedures for identifying, logging, packing, preserving and transporting environmental samples for chemical or physical analysis.

2.0 EQUIPMENT AND MATERIALS

- Sample containers;
- Sample labels;
- Field logbook;
- Pens with waterproof, non-erasable ink;
- Chain-of-custody (COC) forms;
- Custody seals
- Clear plastic sealing tape;
- Coolers for transporting samples to the laboratory;
- Ice (if required)
- Gallon-size sealable plastic bags; and
- Air bills or similar transportation provider forms.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLE IDENTIFICATION

A unique 9-digit identification code will be assigned to each sample retained for analysis on all United States Environmental Protection Agency (USEPA) sites and on a site-specific basis as determined by the project manager. This code will be formatted as a number series with the sample month (2-digit), date (2-digit), year (2-digit) and consecutive sample number (3-digit).

Example: The first sample for a particular phase of an investigation collected on May 18, 2004 would be identified as 051804001, as detailed below.

$$\underbrace{\mathbf{05}}_{\text{Month}}\quad\underbrace{\mathbf{18}}_{\text{Date}}\quad\underbrace{\mathbf{04}}_{\text{Year}}\quad\underbrace{\mathbf{001}}_{\text{Consecutive Sample Number}}$$

Consecutive sample numbers will indicate the individual sample sequence in the total set of samples collected during that phase of investigation.

Duplicate samples will be assigned a unique 9-digit identification code. Samples selected for matrix spike/matrix spike duplicates (MS/MSD) will include “MS/MSD” at the end of the unique 9-digit identification code. The unique 9-digit identification code is compatible with USEPA electronic data submittal requirements. Sample identification numbers will be used on sample labels, COC forms and other applicable sampling activity documentation.

Sample media codes will be noted on field notes and logs using the following media codes:

Sample numbering will consist of up to three components: a three-character alpha Site identification code; a four- to five-character alpha numeric sample type code; and the sample depth below ground surface (bgs, if soil) or the sample depth below top of mudline (sediment). Groundwater samples will typically not include sample depth bgs unless there are multiple intervals sampled in one open borehole. An example of a completely numbered sample, with each component identified follows.

Example: AES-SP01-(0-0.5)

Where: AES – Any Environmental Site

SP01 – Soil probe location number 1

(0-0.5) – soil sample collected 0-0.5 feet bgs

The site identification code (e.g. AES in the sample above) will remain the same for all samples collected at the Site.

The sample type code (SP01) will vary depending on sample type and location. The following are typical alpha codes to be used in the alphanumeric sample type code for samples:

- AS – air sparging sample;
- CF – confirmation soil sample;
- GP – gas probe sample;
- MW – groundwater monitoring well (if deep and shallow wells are sampled for the same location, this type code is modified to DMW (deep well) and SMW (shallow well);
- PZ – piezometer sample;
- RW – recovery well sample;
- SB – soil boring sample;
- SD – sediment sample;
- SP – soil probe sample;
- SS – surface soil sample;
- SR – source material (used if source material is known to exist);

- SV – soil vapor probe sample;
- SW – surface water sample;
- TP – test pit sample; and
- VE – vapor extraction sample.
- WC – waste characterization (may be preceded by S for solid waste or L for liquid waste).

If additional sampling type codes are required, they will be specified in the site-specific work plan.

When completing soil borings and probes, if a water sample is collected from an open boring or probe location a "w" will be attached to the end of the alpha-numeric sample type code (e.g., SB01W). The numerical portion of the sample type code will indicate the sample location (i.e., boring location 01, 02, 03, etc.).

5.0 SAMPLE LABELING

The following information will be included on each sample label: site name/client, sample number, name of sampler, sample collection date and time, depth of sample (if applicable), analyses or tests requested and preservations added. Information known before field activities (site name, analyses requested, etc.) can be preprinted on sample labels. Duplicate sample labels can be prepared when various sample aliquots must be submitted separately for individual analyses.

6.0 SAMPLE DOCUMENTATION

The following itemized list will be used as a general reference for completion of sample documentation:

- Record all pertinent sample activity in the field logbook in accordance with SOP SAS-01-01, Field Documentation and Reporting.
- Make or obtain a list of samples to be packaged and shipped that day.
- Determine number of coolers required to accommodate the day's shipment based on number of samples to be shipped, number of containers per sample and number of sample containers that will fit in each cooler.
- If samples are shipped by Federal Express or other express shipping service, complete an air bill.

- Assign chain-of-custody form to each cooler and determine which sample containers will be shipped in each cooler. (Note: More than one chain-of-custody form may be needed to accommodate number of samples to be shipped in one cooler).
- Determine which samples will be shipped under each chain-of-custody form. Each day that samples are shipped, record chain-of-custody form numbers, and air bill numbers (if used) in field logbook. Cross-reference air bill and chain-of-custody numbers.
- Complete COC forms in accordance with SOP SAS-03-02, Chain of Custody.
- Assign custody seals to each cooler and temporarily clip seals to each chain-of-custody form.
- Group paperwork associated with each cooler with a separate clip.
- Obtain necessary field team members' full signatures or initials on appropriate paperwork.

7.0 SAMPLE PACKING FOR TRANSPORT

The steps outlined below will be followed to pack the sample containers into coolers for shipment.

1. Each glass sample container will be wrapped with protective packing material.
2. Packing material will be placed in the bottom of each cooler for cushioning.
3. Sample containers will be placed inside each cooler, taking care not to overfill the cooler.
4. Ice will be double bagged sealable plastic bags and added to the cooler on top of the samples. Sample containers will be packed so that they are not in direct contact with ice. The remaining empty space in each cooler will be filled with packing material.
5. Packing material will be placed over the top of the bagged ice.
6. The chain-of-custody records will be signed, and the date and time at which the coolers are sealed for transport by a shipping company, or relinquished to a delivery service or the laboratory sample receiving department will be indicated.
7. Copies of chain-of-custody records will be separated. The original signature copies will be sealed in a large, sealable, plastic bag and taped to the inside lid of a cooler. A copy of each COC will be retained by the Site Manager.
8. If any cooler has a drain, the drain will be taped shut.
9. The lid to each cooler will be closed and latched. Custody seals will be affixed to each cooler between the lid and the body of the cooler. One custody seal will be placed on the front of the cooler, and one will

be placed on the back. Custody seals will be covered with clear plastic tape. An example of a custody seal is located in SOP SAS-03-02, Chain-of-Custody.

10. The cooler will be closed and taped shut on both ends with several revolutions of tape. Also, tape will be wrapped several times around the cooler body and the cooler lid to firmly secure the cooler lid and body together.
11. Samples will be packed and transported to the analytical laboratory within one day of collection.

8.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D3694-96(2004) Standard Practices for Preparation of Sample Containers and for Preservation of Organic Constituents

ASTM International, D4220-95R00 Practices for Preserving and Transporting Soil Samples

ASTM International, D4840-99(2004) Standard Guide for Sampling Chain-of-Custody Procedures.

ASTM International, D6911-03 Guide for Packaging and Shipping Environmental Samples for Laboratory Analysis

International Air Transport Association (IATA), 2005, Dangerous Goods Regulations.
USEPA, 1981, *Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples*, Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273), April 13, 1981.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

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STANDARD OPERATING PROCEDURE NO. SAS-03-02

CHAIN OF CUSTODY Revision 0

1.0 PURPOSE

This Standard Operating Procedure describes procedures for preparation and use of the chain of custody (COC) form that accompanies field-collected soil, sediment, water, air or geotechnical samples. Procedures are also provided for preparation and use of custody seals for securing openings of sample containers during transport of samples to the analytical laboratory. COC forms and custody seals are used to provide documentation of sample integrity from the time of collection to time of sample receipt and acceptance by the analyzing laboratory or testing laboratory.

2.0 EQUIPMENT AND MATERIALS

- COC forms;
- Custody seals;
- Gallon-size plastic sealable bags; and
- Clear plastic packing tape.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 METHODS/PROCEDURES

4.1 Chain of Custody Form Items to Complete

Attachment A presents an example COC form. The following general information must be completed on the COC form:

- Laboratory name, address, telephone number;
- Document control number;
- Site manager name on Attention line;
- Project number;
- Site name;
- Complete field sample identification number;
- Sample collection date for soil, sediment and water samples or sample start and collection dates for ambient air monitoring samples;
- Time of sample collection for soil, sediment and water samples or sample start and collection times for air monitoring samples;
- Sample matrix (i.e. liquid, solid, or gas);
- Number of containers;
- Analysis or testing method requested;
- End pressure, Summa can identification number, and flow controller serial number for air monitoring BTEX samples and filter identification number for air monitoring PM10 samples.
- Sample preservatives used (other than ice) in Remarks column;
- Turn-around time requested (specify if turn-around time is business or calendar days) in Special Instructions box;
- Signature of person(s) conducting sampling;
- Strike line with samplers initials and the date samples are relinquished in order to complete unused portion of COC form;
- Signature of person relinquishing the sample custody (person relinquishing custody must be a sampler to ensure chain of custody is maintained);
- Signature of person transporting samples to the lab if other than sampler/relinquisher or third-party carrier;

- **DO NOT** write "FedEx" or other third-party carrier's name in the Relinquished To box. The air bill and carrier's established custody documentation procedure is used to verify custody during transportation.
- Date and time samples are relinquished;
- Custody seal identification numbers; and
- Freight bill identification number in Special Instructions box or at bottom of Remarks column (if third party shipper is used to transport).

4.2 Chain of Custody Form and Procedures

- If a sampling event requires the use of more than one shipping container (cooler for soil/sediment/water samples or box for certain air monitoring samples or soil samples for geotechnical testing) a separate COC form must be completed for each shipping container. For each container, the associated COC form must list only the samples contained in that container.
- When it is known that numerous chains of custody will be required for a project or for a single sampling event, it is acceptable to pre-type the laboratory name, address, telephone number, project number, site name, 3-letter project name abbreviation in Document Control Number area, and site manager name. These are the only information fields that may be pre-typed.
- Each COC should contain a unique document control number in the format: 3-letter project name abbreviation – identification number – 4 digit year, e.g. AES-001-2006, AES-002-2006 and so on. For each project COC identification numbers should be assigned sequentially beginning with 001 for each calendar year. (Exception: for remediation ambient air monitoring projects that span two or more calendar years, continue sequential numbering throughout the project.)
- The COC form must be completed in ink.
- Corrections must be made by drawing a single line through the data that is in error and initialing and dating at the end of the line. The use of correction fluid or tape is not allowed. Do not write over text or numbers to correct. If multiple corrections are needed, copy correct information to a new COC and destroy copy with errors.
- If the number of samples included in the shipping container is less than the number of data entry lines on the COC, draw a single diagonal line running from left down to the lower right hand corner of the field sample data area. The sampler's initials and date must appear along the line.

- Seal the completed COC form in a plastic storage bag. For cooler shipping containers, tape the bag to the inside of the cooler lid prior to sealing the cooler. For box shipping containers, insert the bagged COC form into the box prior to sealing the box.
- If samples are to be shipped by a third party carrier (e.g. Federal Express) the third party carrier does not need to sign the chain of custody. The COC form may be sealed inside the container prior to shipping. If samples are to be hand-delivered to a laboratory by someone other than the sampler/relinquisher (e.g., site construction manager or laboratory courier), the sampler/relinquisher must transfer custody by having the carrier sign in the "Received By" section of the COC form and enter the date and time of transfer. Then seal the COC form inside the container.

4.3 Custody Seal Procedures

A sample custody seal is a strip of adhesive paper used to detect unauthorized tampering with samples prior to receipt by the laboratory. Attachment A presents an example of a completed custody seal. Custody seals are pre-numbered and should be used instead of laboratory custody seals whenever possible.

- A minimum of two custody seals are used per shipping container, one on each long side of the cooler or across each opening of a box. For coolers, one of the custody seals must be placed from the lid to the side of the cooler such that it would be necessary to break the seal in order to open the shipping container. Cover each custody seal with a single piece of clear packing tape wrap it around the perimeter of the cooler. For boxes, place a custody seal across each opening of the box (top and bottom) and cover with a piece of packing tape, making sure tape is secured in such a way that it cannot easily be removed.
- The relinquisher must sign and date each custody seal in ink and include the site identification abbreviation in the custody seal number area.
- Each custody seal has a pre-printed unique six-digit identification number. This number along with the site identification abbreviation must be transferred exactly to the Custody Seal Number box on the COC. The identification number of all custody seals used in conjunction with the COC must be listed on the COC. If a custody seal other than the pre-numbered one, a unique identification number must be printed on the seal and transferred exactly to the Custody Seal Number box on the COC.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

A copy of the COC forms and freight bills used in the above procedure will be transferred to the Project Manager and maintained in the project-specific file as part of the official chain of custody record.

6.0 QUALITY CONTROL AND QUALITY ASSURANCE

- Each COC will be checked for accuracy and completeness (i.e. sample list complete, sample data entered correctly etc.) by another member of the field sampling team before samples are relinquished for transport. In the event the sampler is the sole person on-site, the COC will be checked for accuracy and completeness within 24 hours of the sampling event by a member of the project team.
- Review of the COC forms and freight bills used in the above procedure will be conducted during evaluations of sampling procedures by personnel. The COC forms will also be reviewed as part of the data validation process when the laboratory returns the completed COCs following receipt and analysis of samples.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM, International, 1999, D 4840-99 (2004) Standard Guide for Sample Chain-of-Custody Procedures.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
EXAMPLE CHAIN-OF-CUSTODY AND CUSTODY SEAL FORMS

Request for Chemical Analysis and Chain of Custody Record

Send Results to:	Laboratory:	Document Control No.:
	Address:	Lab. Reference No. or Episode N
Attention:	City/State/ZIP:	
	Telephone:	
Project Number:		Sample Type
Site Name:		Matrix

Sample Number			Sample Event		Sample Depth (in feet)		Sample Collected		Liquid	Solid	Gas	Number of Containers	Parameter/Method Code						Remarks
Group or SWMU Name	Sample Point	Sample Designator	Round	Year	From	To	Date	Time											

Sampler *(Print Name)*:		Sampler *(signature)*:	Custody Seal Number	Special Instructions	
Relinquished By *(signature)*: 1.	Date/Time	Received By *(signature)*: 1.	Date/Time	Ice Present in Container: Yes ☐ No ☐	Temperature Upon Receipt:
Relinquished By (signature): 2.	Date/Time	Received By (signature): 2.	Date/Time	Laboratory Comments:	

Signature ______________________________

Date ______________ # ______ -112504

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STANDARD OPERATING PROCEDURE
NO. SAS-03-03

SAMPLE LOCATION IDENTIFICATION AND CONTROL
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the identification of sample locations and field measurements of topographic features, water levels, geophysical parameters, and physical dimensions frequently required during groundwater, hazardous waste, and related field investigation activities. The scope of such measurements depends on the purpose of the field investigation. Samples collected from each sampling location will have a unique sample identified in accordance with ENV-03-01.

All sampling locations shall be uniquely identified and depicted on an accurate drawing or a topographic or other site map, or be referenced in such a manner that their location(s) are established and reproducible. A sample location must be identified by a coordinate system or other appropriate procedures which would enable an independent investigator, to collect samples from reproducible locations. Repetitive sampling might be performed, for example, to monitor the progress of a remedial program, to check for suspected erroneous results from an initial sampling, or to check the reproducibility of results.

2.0 EQUIPMENT AND MATERIALS

- Site map;
- Surveying equipment;
- Measuring tape;
- Field notebooks/logs; and
- GPS unit.

3.0 SAMPLE LOCATION IDENTIFICATION

Locations for collection of samples are assigned alphanumeric codes which are used to coordinate laboratory data tracking and graphic depiction of sample locations on drawings and figures. Samples collected from each sampling location will have a unique sample identified in accordance with ENV-03-01. Each sample location is issued a unique numeric code that corresponds to a specific map location on a plan view of a site and vicinity. An alpha-code (letter) is used to describe the type of sampling activity performed at the specific numeric location. The following alpha codes will be used:

Air	AS	Air Sparging Point
	GP	Gas Probe
	GM	Gas Monitoring Well
	SV	Soil Vapor Probe
	VE	Soil Vapor Extraction Well
Material	AC	Asbestos Containing Material
	LS	Lead Wipe Sample
Sediment	SD	Sediment
Soil	SB	Soil Boring
	SS	Surface Soil
	TP	Test Pit
	EB	Excavation Base
	EW	Excavation Well
Water	MW	Groundwater Monitoring Well
	PZ	Piezometer
	PW	Potable Water Well
	RW	Recovery Well
	TW	Temporary Monitoring Well
	SW	Surface Water
	SG	Surface Water Staff Gauge

A typical series of alpha numeric codes for a site might include test pit locations TP01 through TP12; borings SB01, SB02, SB03; monitoring wells MW01, MW02, MW03, etc.

Each sample location will have only one alphanumeric code. A borehole drilled for the purpose of installing a monitoring well will be identified as MW01. There should not be a location SB01 for soil sample location identification and MW01 for groundwater sample location identification.

Note that soil borings performed for the purpose of collecting a groundwater grab sample (e.g. through screened auger, open borehole, Geoprobe®, Hydro-Punch®, etc.) are identified as soil borings, not monitoring wells. These types of sampling locations may be further identified on site figures with a clarifying suffix (GW), such as SB01(GW). The site map legend will explain the meaning of all symbols used to identify sampling points.

If previous work has been performed at a site, the alphanumeric code should continue with previous successive numbers. If there is any potential for conflict with existing sample number identifiers, the proposed sample number should begin with series 101, 1001, or other appropriate system. Dashes should be eliminated from sample number identifiers, such as SB101 should be used instead of SB-101.

4.0 SURVEYED LOCATIONS

Survey control should be performed following monitoring well and borehole installations by a surveyor licensed in the state of the project site. Vertical elevations to the top of each new well casing will be established within ± 0.01 foot. Ground surface elevations at each well and borehole location should be established within ± 0.01 foot. Elevations should be referenced to the North American Vertical Datum of 1988 (NAVD 88). Alternative systems may be used on a project-specific basis, with appropriate reference documentation in the master project file and final reports.

Lateral locations based on an established grid system will be determined for each sampling location. Lateral locations should be calculated to within ± 1-foot. The site map should include at minimum sampling locations, structure boundaries, property boundaries, nearby surface water, site grid system origin according to either a state plane coordinate system or latitude and longitude, bar scale, and a north arrow. Specific state reporting and mapping requirements should be checked prior to final plan development.

In conducting vertical surveys, the following procedures should be used or should be referenced in subcontractor service agreements with licensed surveyor:

- When practical, level circuits will close on a bench mark other than starting bench mark;
- Readings should be recorded to the closest 0.01 foot using a calibrated rod;
- Foresight and backsight distances should be reasonably balanced;
- Rod levels should be used;
- No side shot should be used; and
- Benchmarks should be traceable to USGS benchmarks.

Field staff and contractors will record all field data collected during survey activities in accordance with SOP SAS-01-01 for incorporation into site data reports, maps, tables, etc.

5.0 TRIANGULATION

Triangulation shall be used if a registered surveyor is not contracted. This method encompasses distance measurement from sampling points relative to two and sometimes three known points. Distance measurements should be accurate to within ±1 foot allowing for sag in the measuring tape and other inaccuracies. Measuring to two known points is typically adequate for rough measurements made with a pocket transit and 100-foot tape; however, measuring to three known points reduces potential error. Distance measurements should be made relative to distinctive features having a probable life span in excess of 10 years. Examples include the following:

- Power pole located on north side of plant entrance #1 driveway;
- SE corner of plant building 2 located at 111 Survey Circle; or
- NW corner of retaining wall running north-south along Bass Creek.

Unacceptable triangulation points include fence posts, trees, temporary stakes or markers etc., unless these features are to be located within 15 days by survey.

When locating sampling points, decide which site features will be important to illustrate on a site map in the report. If appropriate, also locate areas of known or suspected spills and manholes which may represent migration pathways. Establish relative locations of these and other pertinent site features by triangulation.

The client should be consulted regarding the existence of plant drawings or other surveyed maps which accurately show the relative location of major site features. The field notebook should record information describing the drawing (e.g., who it was prepared by, date, drawing number, etc.) and describe the points on the drawing being used for triangulation purposes.

If only one site feature is convenient for triangulation, the remaining two reference points can be established by running a line toward a more distant site feature, which can be easily located later, and the recorded distance from a defined point along that line.

6.0 GLOBAL POSITIONING SYSTEM (GPS)

Global Positioning System (GPS) is an appropriate method to determine the location of site investigation features in limited circumstances, and is solely at the discretion of the project manager.

There are significant accuracy limitations with GPS which limits the effectiveness of this technology in the role of sample location. For sites where accuracy less than ± 10 feet is acceptable, or surveying is impractical, GPS is a suitable sample location method. GPS is not suitable for sites requiring a higher degree of accuracy. However, the recording of GPS coordinates is encouraged for all sites where monitoring wells or other permanent features may be obscured by snow, vegetation, or other obstructions. In such cases, GPS may assist in locating the monitoring well, etc. despite the accuracy limitations.

7.0 REFERENCES

ASTM International, 2002, D5906-02 Guide for Measuring Horizontal Positioning During Measurements of Surface Water Depths.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

Zilkoski, David B., J.H. Richards, and G.M. Young , 1992, Results of the General Adjustment of the North American Vertical Datum of 1988, American Congress on Surveying and Mapping, Surveying and Land Information Systems, Vol. 52, No. 3, 1992, pp.133-149.

SOP SERIES SAS-04

SAMPLING QUALITY CONTROL

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STANDARD OPERATING PROCEDURE NO. SAS-04-03

QUALITY CONTROL SAMPLES Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of quality control (QC) samples. QC samples are utilized to evaluate field and laboratory quality control procedures and the precision, accuracy, representativeness and comparability of data obtained during investigative activities.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials for the collection and analysis for quality control samples shall be identical to those used for the collection and analysis of the sample of similar media and collection method.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 QUALITY CONTROL SAMPLES

QC samples include field duplicate samples, matrix spike (MS) and matrix spike duplicate (MSD) samples, trip blanks, and field/equipment blanks.

4.1 Field Duplicate Samples

Duplicate samples are collected from various media to evaluate the representativeness and comparability of data obtained during investigative activities. These samples shall be collected at the same time, using the same procedures, the same equipment, and in the same types of containers as the original sample. They shall also be preserved in the same manner and submitted for the same analyses as the requested analytes. The minimum/required frequency of duplicate sample collection for each sample media shall be specified in the Quality Assurance Project Plan (QAPP), Field Sampling Plan (FSP), and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

4.2 Matrix Spike and Matrix Spike Duplicate Samples

MS/MSD samples are collected from various media to evaluate the precision and accuracy of laboratory procedures. As with field duplicate samples, MS/MSD samples shall be collected at the same time, using the same procedures, the same equipment, and in the same types of containers as the original sample. They shall also be preserved in the same manner and submitted for the same analyses as the requested analytes. The minimum/required frequency of MS/MSD sample collection for each sample media shall be specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the (QAPP).

4.3 Trip Blanks

Trip blanks are used as control or external quality assurance/quality control (QA/QC) samples to detect contamination that may be introduced in the field, in transit to or from the sampling site, or in bottle preparation, sample log-in, or sample storage sites within the laboratory. Trip blanks will also reflect contamination that may occur during the analytical process. Trip blanks are samples of reagent free water, properly preserved, which are prepared in a controlled environment prior to field mobilization. These samples are prepared by the analytical laboratory. The trip blanks are kept with the laboratory provided containers through the sampling process and returned to the laboratory with the other aqueous samples for VOC analysis. Trip blanks must be used for samples intended for VOC analysis and are preserved and analyzed for

VOCs only. One trip blank will accompany each cooler containing aqueous samples for VOC analysis or as specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

4.4 Field/Equipment Blanks

Field/equipment blanks are used to determine 1) if non-disposable equipment decontamination procedures are being carried out properly and there is no "carryover" from one sample to another and 2) ensure that disposable equipment is free of measurable concentrations of constituents of potential concern. Field/equipment blank shall be collected by pouring distilled or ultrapure/DI water onto or into the sampling equipment and direct filling the appropriate sample containers with the DI water from the sampling equipment. Field blank will be handled and treated in the same manner as all samples collected unless noted otherwise below. Field/equipment blanks are always collected after sampling equipment has been decontaminated and may be performed prior to collecting the first sample, after collecting highly impacted samples, and/or at the conclusion of sampling. The minimum/required frequency of field/equipment blanks for each sample media shall be specified in the QAPP, FSP, and/or Site-Specific Work and/or Sampling Plan(s). If the frequency of collection is in conflict between the above-mentioned documents, the Site-Specific Work shall take precedence. The evaluation of these samples is described in the QAPP.

5.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, 1990, Quality Assurance/Quality Control Guidance for Removal Activities, Sampling QA/QC Plan and Data Validation Procedures, Interim Final, EPA/540/G-90/004.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, 2002a, Quality Management Plan for the Superfund Division, Region 5, Chicago, Illinois.

USEPA, 2002b, Guidance for Quality Assurance Project Plans, EPA QA/G-5/ EPA/240/R-02/009.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE NO. SAS-04-04

EQUIPMENT DECONTAMINATION Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for decontamination of equipment prior to its 1) initial use onsite 2) reuse at another sampling interval or location, and 3) demobilization from Site as specified in the Site-Specific Work Plan or as otherwise specified. Personnel decontamination is described in the site-specific Health and Safety Plan (HASP).

2.0 EQUIPMENT AND MATERIALS

Decontamination equipment and materials may vary based on the size or type of equipment, but generally include the following:

- Decontamination detergents (e.g. Alconox);
- Tap water;
- Deionized, distilled and organic-free water;
- Acid solution (optional);
- Approved cleaning solvent (e.g. isopropanol, hexane, Stoddard) (optional and/or site-specific);
- Metal scrapers;
- Brushes;
- Buckets;
- Steam cleaner or high-pressure, hot water washer;
- Racks, normally metal (not wood) to hold miscellaneous equipment;
- Buckets, 55-gallon drums, or other approved storage containers;
- Plastic sheeting;
- Utility pump (optional);
- Paper towels;
- Personal protective equipment; and

- Logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific HASP based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

4.1 General Requirements

All expected types and levels of contamination shall be discussed during field activity planning and a decontamination plan sufficiently scoped within the Site-Specific Work Plan. Until proven otherwise, all personnel and equipment exiting the area of potential contamination/work zone will be assumed to be contaminated. Personnel involved in decontamination efforts shall be equipped with the same personal protective equipment as those conducting the field activity until a lower level of risk can be confirmed.

Decontamination procedures may be subject to federal, state, local, and/or the client's regulations. All regulatory requirements shall be satisfied, but the procedures adopted shall be no less rigorous than those presented in this SOP.

Climatic conditions anticipated during decontamination activities may impact the implementation of the procedures describe in this SOP. Special facilities or equipment may be needed to compensate for weather conditions (e.g. temporary, heated structures for winter work). In addition, it may be necessary to establish special work conditions during periods of high heat or cold stress.

4.2 Preparation

4.2.1 Site Selection

The equipment decontamination facility or area shall be located in an area where contaminants can be controlled and at the boundary of a "clean zone" or "cold zone". The location shall also be selected to prevent equipment from being exposed to additional or other contamination. When Site layout and size allow, a formal "contamination reduction zone" or "warm zone" shall be established in which decontamination efforts will be conducted. This area shall be conspicuously marked as "off-limits" to all personnel not involved with the decontamination process.

The equipment decontamination facility or area shall also be located where decontamination fluids and materials can be contained and easily discarded or discharged into controlled areas of waste. This facility or area shall have adequate space for the storage of unused and used storage containers, until such time as they can be relocated or disposed of.

4.2.2 Decontamination Pad

Some Site may have an existing decontamination pad. If a decontamination pad has been previously constructed, it shall be evaluated for logistics capabilities, such as water supply, electrical power, by-product handling capabilities, and cleanliness. An existing decontamination pad shall be used or modified to the extent practical. If a decontamination pad is not present or the existing pad cannot be used or modified for use, a pad consisting of a sturdy base, lined with plastic sheeting of high-density polyethylene with four raised sides and a sump for collection of fluids will be constructed unless otherwise specified by the Site-Specific Work Plan. Some field activities, which consist of hand sampling or other small equipment, may not require a decontamination pad. In these cases, buckets, small wash tubs, or small pools may be sufficient for equipment decontamination.

4.2.3 Water Supply

Large volumes of water, often exceeding 1,000 gallons per day, may be required for decontamination activities, especially for drill rigs and other large equipment. The water used for decontamination must be clean, potable water. In most cases, municipal water supplies are adequate. Private potable water supplies shall be evaluated on a case-by-case basis prior to use.

4.2.4 Cleaning Equipment and Supplies

A portable steam cleaner or high-pressure hot water washer is normally required to clean contaminated heavy machinery (e.g. drill rig, backhoe, etc.) as well as materials and associated tools. Most steam cleaners and washers are commercially available for both portable generators or supplied AC power. Site logistical considerations may dictate the type of equipment required. Typical steam cleaners/washers operated on relatively low water consumption rates (2 to 6 gallons per minute) and can be used in conjunction with other cleaning fluids mixed with the water. High-pressure steam is preferred to high-pressure water because of steam's ability to volatilize organics and to remove oil and grease from equipment. Since units tend to malfunction easily and are susceptible to frequent maintenance and repair (especially under frequent use and freezing conditions), a second or back-up unit should be available onsite or arranged for with a nearby vendor to the extent practical, for longer duration field activities.

Garden sprayers may be used for final rinsing or cleaning. However, these sprayers shall be limited to use with small hand tools and sampling equipment. Since these sprayers tend to malfunction or break down easily, a second or backup sprayer shall be maintained onsite.

Metal scrapers and brushes shall be used to physically remove heavy mud, dust, etc. from equipment prior to and during the equipment rinses. Scrapers and brushes are relatively inexpensive and shall be replaced as necessary to support cleaning activities.

Decontamination solutions may consist of the following:

- Laboratory detergent shall be a standard brand of laboratory detergent such as Alconox® or Liquinox®;
- Nitric acid solution (10 percent) will be made from reagent-grade nitric acid and deionized water;
- Cleaning solvent;
- Potable water;
- Deionized water;
- Distilled water; and
- Organic-free water.

The use of cleaning solvents shall be carefully considered prior to use with respect to safety, handling and disposal, and potential impact to analytical results and the environment.

Potable, deionized, distilled, and organic-free water should contain no heavy metals or other inorganic compounds (i.e., at or above analytical detection limits) as defined by a standard Inductively Coupled Argon Plasma Spectrophotometer (ICP) scan and no pesticides, herbicides, extractable organic compounds, and less than 5 µg/l of purgeable organic compounds as measured by a low-level GC/MS scan. The level of QA/QC required during the project to verify and document the purity of the water and the number of rinsate blanks required to verify and document the effectiveness of decontamination procedures shall be based on data quality and project objectives as specified by the Site-Specific Work and/or Quality Assurance Project Plan (QAPP). The use of non-potable or untreated potable water supply for decontamination is not acceptable.

4.3 Equipment and Vehicle Decontamination Procedures

4.3.1 General Procedures

The following procedures are presented as general guidelines and shall be followed unless otherwise required by the Site-Specific Work Plan or otherwise specified:

1. Physical removal of particles;
2. Steam or water wash with potable water to remove particles;
3. Rinse critical pieces of equipment with an approved cleaning solvent or nitric acid solution (optional and/or site-specific);

4. Steam or water wash with a mixture of detergent and potable water;
5. Steam or water rinse with potable water; and
6. Air dry.

4.3.2 Special Case – Drilling Equipment

During decontamination of drilling equipment and accessories, clean auger flights, drill rods, and drill bits as well as all couplings and threads. Generally, decontamination can be limited to the back portion of the drill rig, drill rig tires, drill rig mast, and parts that come in direct contact with samples or casings or drilling equipment placed into or over the borehole.

Some items of drilling equipment cannot typically be decontaminated. These items include wood materials (e.g. planks), porous hoses, engine filters, etc. These items shall not be removed from site until ready to dispose of in an appropriate manner.

Other drilling equipment that requires extensive decontamination is water or grout pumps. Circulating and flushing with a potable water and detergent solution followed by potable may be sufficient to clean them. However, if high or unknown contaminant concentrations or visible product is known to exist, then disassembly and thorough cleaning of internal parts shall be required before removal of the equipment from the Site.

4.4 Sampling Equipment Decontamination Procedures

4.4.1 General Procedures

Sampling equipment shall be decontaminated prior to its 1) initial use onsite 2) reuse at another sampling interval or location, and 3) demobilization from Site using the following procedure as general guidelines unless otherwise required by the Site-Specific Work Plan or otherwise specified:

1. Physical removal of particles;
2. Rinse with an approved cleaning solvent or nitric acid solution (optional and/or site-specific);
3. Wash and scrub with a detergent and potable water solution;
4. Rinse with potable water;

5. Rinse with high-grade water (deionized, distilled, or organic-free);
6. Air dry; and
7. Wrap in aluminum foil, shiny side out, for transport.

4.4.2 Special Cases

Steel tapes, water and interface probes, transducers, and thermometers, shall be cleaned with a detergent solution and rinsed with high-grade water. Water quality meters shall be rinsed with high-grade water.

Pumps with internal components that contact a water sample (e.g., bladder pump) shall be deconned by pumping a detergent solution (minimum two gallons) followed by potable water rinse (minimum two gallons) and a high-grade water rinse (minimum two gallons). If field conditions (e.g., the presence of product) indicate circulating and flushing a pump with a detergent solution followed by potable water is not an adequate field decontamination procedure, the pump shall be disassembled and internal parts thoroughly cleaned with a detergent solution followed by potable water rinse and a high-grade water rinse.

4.5 Well Material Decontamination Procedures

Well construction materials, including end cap, screen, and riser pipe, whether polyvinyl chloride (PVC), stainless steel, or other material shall be cleaned with a steam cleaner or high-pressure hot water washer before it is installed in the borehole. Well construction materials shall be handled while wearing latex, nitrile, or equivalent gloves.

4.6 Equipment Segregating and Labeling

Decontaminated equipment shall be stored separating from contaminated equipment in a manner that prevents the recontamination of “clean” equipment. Equipment that is cleaned utilizing these procedures shall receive a final decontamination process at the completion of field activities and will be tagged, labeled, or marked with the date that the equipment was cleaned.

4.7 Disposal Practices

4.7.1 General Disposal Requirements

Disposal practices shall be in accordance with the procedures specified in the Site-Specific Work Plan. Decontamination derived waste shall be contained, consolidated, and disposed shall be conducted to prevent the spread of contaminants offsite or to "clean" locations onsite and in a manner consistent with the acceptable disposal practices for the type and concentration of wastes that may be contained in the decontamination derived waste. Contaminated equipment or solutions shall not be discarded in any manner that may lead to the contamination of the environment by the migration of hazardous constituents from the Site by air, surface, or subsurface transport mechanisms.

4.7.2 Onsite Storage, Treatment, and Disposal

On controlled, secured facilities, most decontamination derived waste shall remain onsite pending waste characterization and disposal. The decontamination derived waste shall be labeled and stored in a manner that does not pose a threat to contamination of personnel or areas to be sampled or a threat of release to the environment. Liquids and solids shall be containerized separately in approved storage containers. Each storage container shall be labeled with the following:

- Contents (e.g. decontamination fluids);
- Incompatibilities (if applicable);
- Accumulation date; and
- Contact person and phone number.

In some cases, an onsite treatment system is available for certain types of decontamination derived waste. Treatment of decontaminated derived wastes shall be performed in accordance with any applicable permit requirements and federal, state, and local laws and regulations.

In some cases, certain materials that are not contaminated or contain very low levels of contamination may be disposed of onsite. Such materials may include may include drill cuttings, wash water, drilling fluids, and water removed during the purging or sampling of wells. The low level of contamination (concentrations below applicable cleanup objectives) shall be confirmed prior to onsite disposal. Onsite disposal shall comply with federal, state, and local laws and regulations.

4.7.3 Offsite Disposal

In most cases, decontamination derived waste cannot be disposed of or treated onsite. Decontaminated derived waste shall be properly characterized prior to shipment to a licensed and approved treatment, storage, and disposal facility. Decontamination fluids discharged to sanitary and/or storm sewers shall be properly permitted prior to discharge. Offsite disposal shall comply with federal, state, and local laws and regulations.

5.0 DOCUMENTATION

Decontamination activities, including deviations for general procedures, shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work.

6.0 REFERENCES

ASTM International, D5088-02 Practices for Decontamination of Field Equipment Used at Waste Sites.

USEPA, Region IV, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

SOP SERIES SAS-05

SUBSURFACE INVESTIGATION METHODS

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STANDARD OPERATING PROCEDURE
NO. SAS-05-01

SUBSURFACE EXPLORATION CLEARANCE
Revision 0

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to ensure intrusive site activities are conducted with the knowledge and approval of property owners, utility providers, and governmental agencies, as appropriate, in a manner that minimizes potential exposure to subsurface hazards and damage to subsurface utilities. Clearance of intrusive activity areas must be obtained from appropriate authorities and site operators. This clearance comes in the form of 1) permission to enter a property, 2) ensuring subsurface conditions will not be encountered that endanger the safety of site personnel, subcontractors, and authorized visitors, and 3) demarcation of subsurface utilities/structures.

2.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

3.0 SITE ACCESS AND ENTRY

Access to properties subject to activities conducted under the contracted scope of services/work order is the responsibility of the client as set forth in the environmental engineering and consulting services agreement. The client will give reasonable access to client-owned properties for performance of services. If the client does not own or operate the property, it will secure an access agreement or other authorization for consultant access to the site that will address the terms of access as well as any access restrictions.

Site entrance procedures are as follows:

- The client will be advised of the date and time of site entrance and the purpose of the entrance.
- In addition, if the site is not owned by the client, the owner of the property will be advised of the date and time of site entrance and the purpose of the entrance.
- Entrance to the site shall be through the main gate or other entrance specified by the client or owner.
- If a site contact is present at the site, the consultant will introduce herself/himself and provide the site contact with a business card. The consultant shall also identify other personnel who are or will be on-site and explain their functions.
- The consultant will complete any general sign-in procedures required for site entrance, unless otherwise instructed by the client or property owner.
- If a liability waiver is presented that is not pre-agreed to by the consulting company and the client or owner, the consultant will call her/his Project Manager for instructions.
- If entry is refused, the consultant will leave the site entrance and call her/his Project Manager for instructions.
- The time of site entrance, or refusal of entrance will be included in the field logbook entry for the day.

4.0 SITE CLEARANCE

Site clearance is required prior to commencement of any investigation or remediation activities. Three categories of site clearance are required:

1. Property boundary identification,
2. Utility clearance, and
3. Clearance of any on-site subsurface obstructions, hazards or protected structures identified by the client or property owner.

4.1 Property Boundary Identification

The first step in site clearance is to demarcate the property boundaries. A client- or property owner-provided plat of survey will be used if available. If no current plat of survey is available, the client or property owner may be asked to have a licensed surveyor conduct a survey and mark the property boundaries or the consultant may hire a surveyor to conduct the survey on behalf of the client. All property boundaries should be fully known and marked prior to commencement of any site investigation activities. If an investigation location appears to be outside of the property boundaries that encompass the area to which access has been granted, the Project Manager shall be consulted prior to commencement of any activity at that location.

4.2 Utility Clearance

Written clearance of all underground utilities (private, commercial, and public) must be obtained prior to commencing intrusive site activities (e.g. soil borings, GeoProbe advancement, test pit or trench excavation). Utility clearance is vital for safe operations and provides notification to utility companies of intrusive work being conducted in the vicinity of underground lines and structures. The utility clearance process is initiated by calling a state- or city-specific one-call utility clearance hotline. One-call center information may be obtained by calling “811” or visiting http://www.call811.com/state-specific.aspx. Generally, utility clearance must be requested at least 48 hours in advance of the commencement of intrusive activities. In some states, including Illinois, utility clearance is the responsibility of the contractor performing the intrusive work (e.g. drilling subcontractor or excavation company) rather than the contracting environmental consultant.

Assemble the following information to make the call or provide this information to the subcontractor:

- Name, address and phone number of person making request;
- Type and extent (size of excavation) of work being performed;
- Start date and time of excavation;
- Address, including street, number, city, and county (township range, section and quarter section information may also be required);
- Nearest crossroad; and
- General legal description, if available.

The following table lists the one-call-center contact information for the Midwest.

	One Call System Name	Non-Emergency	Emergency	Website
Illinois (except City of Chicago)	J.U.L.I.E. Joint Utility Locating Information for Excavators	(800) 892-0123	- - -	http://www.illinois1call.com
City of Chicago	DIGGER	(312) 744-7000	- - -	http://www.cityofchicago.org
Indiana	I.U.P.P.S. Indiana Underground Plant Protection Service	(800) 382-5544	- - -	http://www.iupps.org
Iowa	Iowa One Call	(800) 292-8989	(800) 292-8989	http://www.iowaonecall.com
Kansas	Kansas One Call	(800) 344-7233	- - -	http://kansasonecall.com
Michigan	MISS DIG System Inc.	(800) 482-7171	- - -	http://www.missdig.org/MissDig/
Missouri	Missouri One Call System	(800) 344-7483	- - -	http://www.mo1call.com
Wisconsin	DIGGER	(800) 242-8511	(800) 500-9592	http://www.diggershotline.com

Utility location agencies may only mark-out utilities on public right-of-ways adjacent to the property under investigation and sewer and water departments may not be included in the locating services provided by the one-call centers. Request additional information from any utility companies or public utilities departments not included in the one-call locating services. It may be advisable at some properties to hire a private utility locating contractor to do additional on-site clearance prior to commencement of intrusive activities. Consult with the Project Manager about conducting additional locating activities if the information provided by the one-call center is not complete with respect to what is known about possible underground utilities at the site.

Do not proceed with any intrusive activities until all utility clearances and mark-outs have been performed by the locating services or participating utility companies. Do not proceed without verification from the subcontractor that the utility clearance has been performed if it was the subcontractor's responsibility to request the utility locating service. Prior to start of intrusive activities, walk the site and surrounding public right-of-way with the subcontractor locating any utility markers and discuss procedures for avoiding marked utilities during the site investigation. If at any time, a potential hazard exists at a proposed investigation location that cannot be resolved with available information and utility location markings, contact the Project Manager for instructions.

4.3 On-Site Subsurface Obstructions, Hazards and Protected Structures Clearance

The property owner (client or third party) or a designated representative shall also be contacted prior to commencement of any intrusive activities to obtain additional information regarding on-site subsurface obstructions, hazards or protected structures and clearance to conduct the activities in pre-determined locations on the site. If possible, as part of the investigation planning activities, obtain architectural or engineering drawings of the site that include building layouts and locations of subsurface utilities and structures. Schedule an on-site meeting prior to commencement of activities to review locations of proposed locations for intrusive activities. Request that the owner or his authorized representative mark or flag the locations of any known subsurface obstruction, hazard or structure that must not be damaged. In some cases, it may be appropriate to make a site visit prior to the on-site review meeting to mark out proposed subsurface investigation locations for approval by the owner or his representative. During the review meeting, if verbal approval is given to proceed, make an entry in the field logbook including the date, time and person granting approval along with details of the approval given. Record any refusals of permission to perform intrusive activities in the same manner. Include detailed information regarding the reason for the refusal in the field logbook.

If permission for any proposed intrusive activities is refused by the property owner or his representative, inform the Project Manager. If the investigation location approval meeting is performed on a day scheduled for investigation activity, and any locations are not authorized by the owner or his representative, contact the site manager immediately for instructions. Do not proceed with any intrusive activity in the non-authorized locations unless subsequent approval is forthcoming, and do so only upon receiving approval to proceed from the owner/representative and the site Project Manager. Make a detailed record of the refusal and subsequent resolution in the field logbook.

On vacant or undeveloped sites, or sites located in remote areas, on-site client/owner approval of investigation areas may not be practical. In such situations, prior approval of investigation areas may be obtained from the client or owner by means of a site investigation map that includes investigation locations (boreholes, test pit or trench locations, monitoring wells, etc.). Site features, boundary lines, and any known subsurface utilities or structures shall also be included on the site investigation map to provide the reviewer with adequate information to determine if any subsurface hazards exist in the vicinity of any of the proposed intrusive activities.

5.0 REFERENCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001

USEPA, Region IV, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Enforcement and Investigations Branch, SESD, Athens, Georgia

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STANDARD OPERATING PROCEDURE NO. SAS-05-02

FIELD LOGGING AND CLASSIFICATION OF SOIL AND ROCKS Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for logging and classifying soil samples and rock cores during subsurface explorations as described in the Site-Specific Work Plan, or as otherwise specified, for the purposes of characterizing subsurface geologic conditions at a Site.

2.0 EQUIPMENT AND MATERIALS

General:

- Ruler or tape measure in 0.01-foot increments;
- Field logbook and field boring log forms;
- Pen(s) with waterproof, non-erasable ink;
- Camera;
- 5-gallon bucket and wire or nylon brushes, decontamination water, laboratory grade detergent (Alconox or similar), and paper towels;
- Aluminum foil or roll-plastic; and
- Personnel protective equipment, as appropriate, including nitrile gloves for handling impacted soil samples.

Soil Logging:

- Large sharp stainless-steel knife;
- Slim stainless-steel spatula or carpenter's 5-in-1 tool;
- Color chart;
- Comparative charts; and
- Pocket penetrometer.

Rock Coring and Logging:

- Core box(es);
- Hand lens; and
- Comparative charts.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL PROCEDURES

Geologic logging and material classification shall be conducted only by a trained logging technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist). Field data and observations associated with field logging and material classification shall be documented during logging and for all drilling and sampling activities in accordance with SOP ENV-01-01, Field Documentation and Reporting, if not otherwise specified in this SOP. All field drilling activities should be recorded in a field logbook and/or on a field boring log form. In addition, tools and equipment used while logging boreholes shall be decontaminated between boring/probe locations and prior to each sampling event in accordance with the Quality Assurance Project Plan (QAPP).

5.0 LOGGING AND DOCUMENTATION PROCEDURES

The logging technician shall record all pertinent drilling information in the field logbook and/or on the field boring log form (Attachment A). At a minimum, the following technical information with respect to pre-sampling, drilling operations and observations, and sample recovery loss shall be recorded, if applicable:

- Project name and number;
- Location (well or boring/probe number) or other sample station identification, including a rough sketch;
- Name of the logging technician overseeing the drilling operations;
- Drill rig manufacturer and model;
- Drilling company name and city and state of origin;
- Driller and assistant(s) names;
- Drilling method(s) and fluids used to drill the borehole;
- Drilling fluid manufacturer;
- Drilling fluid gain or loss;
- Depth of drilling fluid loss;
- Water source (e.g. fire hydrant, faucet, municipality, etc.);
- Borehole diameter;
- Borehole start time and date;
- Borehole completion time and date;
- Sample type (e.g. split spoon, macrocore, etc.);
- Hammer weight/drop and blow counts;
- Sample recovery/loss and explanation of loss, if known;
- Drilling rates when applicable to lithology classification;
- Description of soil and/or rock classification and lithology;
- Lithologic changes and boundaries;
- Depth to water (first encountered [during drilling] and stabilized [upon completion of drilling]);
- Total borehole depth;
- Evidence of impact (e.g. staining, odors, free-phase product, etc.);
- Well materials, construction, and placement information (e.g. casing type and diameter, screen type and diameter, etc.);
- Sample identifications and depths for chemical and geotechnical samples;
- A description of any tests conducted in the borehole; and
- Problems with the drill rig or drilling process.

When rock coring is performed, the following information shall also be recorded:

- Top and bottom of cored interval;
- Core length;
- Coring rate in minutes per foot;
- Core breakage due to discontinuities (e.g. natural fractures versus coring-induced breaks);
- Total core breakage; and
- Number of breaks per foot.

6.0 SOIL SAMPLE CLASSIFICATION AND DESCRIPTIONS

6.1 Description of Hierarchy

The required order of terms is as follows:

1. Depth measured in tenths of a foot;
2. Soil color;
3. Major soil type (e.g. CLAY). This descriptor can include the secondary soil constituent as a modifier (e.g. silty CLAY);
4. Unified Soils Classification System (USCS) Group Symbol in parentheses (e.g. ML);
5. Evidence of environmental impacts, if encountered (e.g. free-phase product, staining, sheen, etc.);
6. Other soil components of the sample listed with the appropriate percent descriptor (i.e. “with”, “some” or “trace.”);
7. Consistency, relative density or degree of cementation;
8. Moisture and plasticity, if relevant; and
9. Miscellaneous (e.g. condition of sample, deposition, fractures, seams, bedding dip, bedding features, fossils, oxidation, drilling rate data when applicable for sample classification, etc.).

6.2 Color

The color descriptions will be consistent with the Munsell Soil Color Chart, Geological Society of America (GSA) Rock Color Chart, or as required by the Work Plan or otherwise specified. Write the Munsell color name with the Munsell color identification number in parenthesis following the color name. The major color is listed first with any accessory color(s) thereafter (e.g. clay, yellowish gray (5Y 7/2) with pale green (5G 7/2) mottles). If descriptors are used for other soil components, the color designation follows each descriptor.

6.3 Soil Types

Soil descriptions and classification shall be conducted in accordance with the USCS (ASTM D2488-06). The order and presentation of the primary textural classification terms is as follows:

1. Major soil type (e.g. CLAY). This descriptor can include the secondary soil constituent as a modifier (gravelly, sandy, silty, or clayey). Nouns are unabbreviated (e.g. CLAY); “TOPSOIL” is an adequate single term for the naturally occurring organic soil found at the ground surface. In urban areas, “FILL” is used to denote previously disturbed soil, followed by a description of the major and minor soil components (e.g. “FILL, silty clay with some fine sand”). USCS Group Symbol follows the major soil component in parentheses.
2. Other soil components of the sample are listed in descending order of percentage using adjectives “with”, “some” and “trace.”
3. Using the Wentworth Scale in Attachment E, add size, sorting or angularity modifiers to granular material descriptions as appropriate.

6.4 Consistency and Relative Density

The relative density of cohesionless soils and the consistency of cohesive soils should be included in visual classifications. Attachments B and C can be used in describing the consistency of cohesive soils and the relative density of cohesionless soils, respectively.

A pocket penetrometer will be used to measure consistency of cohesive soils with the result recorded on the field boring log form. Attachment B includes information for determining soil consistency from penetrometer measurements.

6.4 Moisture Content

Moisture Content – Criteria for describing moisture content of soils are described in Attachment D.

6.5 Miscellaneous Descriptions

1. Structure – Some soils possess structural features (e.g. fissures, slickensides, or lenses) that if present, should be described.
2. Accessories or Inclusions – Elements such as rock fragments, fine roots, or nodules are included in the soil description following all other modifiers for the major components of the soil matrix. Any mineralogical or other significant components should be described, as well as man-made or apparently foreign constituents that indicate the presence and possible source of fill material.
3. Environmental Impacts – If monitoring instruments or visual observations indicate the potential presence of environmental impacts, it will be noted in detail. Additional information for describing specific types of impacts may be found in the Work Plan.

To provide consistency in logging soils, tables with additional guidelines for soil description are included in Attachment E.

7.0 ROCK CLASSIFICATION

7.1 Lithology and Texture

The logging technician should describe the lithology of the rock and its mineral composition. The geological name, such as granite, basalt, or sandstone, usually describes the rock's origin. The stratigraphic unit should be identified and assigned the local geological name, if appropriate. Stratigraphic age or period should be identified, if possible. Modifiers will be included to describe the rock texture, including grain size, sorting, packing, cementation, etc. (e.g. interlocking, cemented, or laminated-foliated).

7.2 Color

The color descriptions will be consistent with the Munsell Soil Color Chart, Geological Society of America (GSA) Rock Color Chart, or as required by the Work Plan or otherwise specified. Write the Munsell color name with the Munsell color identification number in parenthesis following the color name. The major color is listed first with any accessory colors thereafter. If secondary or tertiary descriptors are used, the color designation follows each descriptor.

7.3 Hardness

Terms used to describe hardness are described below. One common method to determine hardness is the Mohs Scale of Hardness, which is defined as follows:

Descriptive Term	Defining Characteristics
Very Hard	• Cannot be scratched with a knife. • Does not leave a groove on the rock surface when scratched.
Hard	• Difficult to scratch with a knife. • Leaves a faint groove with sharp edges.
Medium	• Can be scratched with a knife. • Leaves a well-defined groove with sharp edges.
Soft	• Easily scratched with a knife. • Leaves a deep groove with broken edges.
Very Soft	• Can be scratched with a fingernail.

7.4 Weathering

Terms used to describe weathering are described below (ASTM D 5434-03):

Descriptive Term	Defining Characteristics
Fresh	• Rock is unstained. • May be fractured, but discontinuities are not stained.
Slightly	• Rock is unstained. • Discontinuities show some staining on the surface, but discoloration does not penetrate rock mass.
Moderate	• Discontinuous surfaces are stained. • Discoloration may extend into rock mass along discontinuous surfaces.
High	• Individual rock fragments are thoroughly stained and can be crushed with pressure of a hammer. • Discontinuous surfaces are thoroughly stained and may crumble.
Severe	• Rock appears to consist of gravel-sized fragments in “soil” matrix. • Individual fragments are thoroughly discolored and can be broken with fingers.

7.5 Rock Matrix Descriptions

Grain size is a term that describes the fabric of the rock matrix. It is usually described as fine-grained, medium-grained or coarse-grained. The modified Wentworth scale should be used or as required by the Work Plan or otherwise specified.

A description of bedding (after Ingram, 1954) or fracture joint spacing should be provided according to the following:

Spacing	Bedding	Joints/Fractures
< 1 inch	Very thin	Very close
1 – 4 inches	Thin	Close
4 inches to 1 foot	Medium	Moderately close
1 foot to 4.5 feet	Thick	Wide
> 4.5 feet	Very Thick	Very Wide

Discontinuity descriptors are terms that describe number, depth, and type of natural discontinuities. They also describe density, orientation, staining, planarity, alteration, joint or fractural fillings and structural features.

8.0 ROCK CORE HANDLING

The following guidelines shall be followed for rock core handling:

1. Core samples must be placed into core boxes in the sequence of recovery, with the top of the core in the upper left corner of the box.
2. At the bottom of each core run, spacer blocks must be placed to separate the runs. The spacer should be indelibly labeled with the drilling depth to the bottom of the core run regardless of how much core was actually recovered from the run.
3. Spacer blocks should be placed in the core box and labeled appropriately to indicate zones of core loss, if known. Where core samples are removed for laboratory testing, blocks equal to the core length removed should be placed in the box. Note: If wooden core boxes are used, spacer blocks should be nailed securely in place.

4. The core boxes for each boring should be consecutively numbered from the top of the boring to the bottom.
5. The core boxes containing recovered rock cores should be photographed. One core box should be photographed at a time with the box lid framed in the picture to include information printed on the inside of the lid. Be sure to include a legible scale in the picture. Photographs are taken in the field most easily and efficiently with natural light and while the core is fresh.
6. When transporting a boxed core, the box should be moved only if the lid is closed and secured with tape or nails.

9.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2007, D653-07b Terminology Relating to Soil, Rock, and Contained Fluids.

ASTM International, 1999, D1586-99 Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM International, 2006, D2488-06 Practice for Description and Identification of Soils (Visual-Manual Procedure).

ASTM International, 2001, D4083-89R01E01 Practice for Description of Frozen Soils (Visual-Manual Procedure).

ASTM International, 2007, D4543-07 Practice for Preparing Rock Core Specimens and Determining Dimensional and Shape Tolerances.

ASTM International, 2002, D5079-02 (2006) Practice for Preserving and Transporting Rock Core Samples.

ASTM International, 2003, D5434-03 Guide for Field Logging of Subsurface Explorations of Soil and Rock.

ASTM International, 2000, D5715-00 (2006) Test Methods for Estimating the Degree of Humification of Peat and Other Organic Soils (Visual/Manual Method).

ASTM International, 2004, D6236-98 (2004) Guide for Coring and Logging Cement- or Lime-Stabilized Soil.

ASTM International, 2004, D7099-04 Terminology Relating to Frozen Soil and Rock.

Johnson, R.B., and J.V. DeGraff, 1988, Principles of Engineering Geology, John Wiley and Sons, New York.

U.S. Army Corps of Engineers, 2001, Engineering Manual EM1110-1-1804 - Engineering and Design - Geotechnical Investigations, January 1.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

Wentworth, C.R., 1922, A scale of grade and class terms for clastic sediments, Journal of Geology, 30: 377-392.

ATTACHMENT A
DRILLING LOG

Drilling Log

	Project Name		Project No.	Boring/Monitoring Well Number
	Site-Specific Coordinates		Ground Elevation	Page 1 of 1
	Total Depth (feet)	Hole Size (inches)	Driller (s)	
Drilling Rig			Drilling Company	
Date / To	Logged By:		Reviewed by:	Approved by:

Elevation (feet)	Depth (feet)	Description	Graphic Log	SAMPLING: Sample Type	Sample Interval	Blow Counts per 0.5'	N Value	Sample Recovery/Length (feet)	Penetro-meter (TSF)	PID Reading (PPM)	Remarks (▽ Depth to water while drilling; ▼ Depth to water after drilling)
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										

ENVIRONMENTAL LOG COPY OF OSI 2003.GPJ BURNS_MO.GDT 8/30/07

ATTACHMENT B
CONSISTENCY OF COHESIVE SOILS

CONSISTENCY OF COHESIVE SOILS

Consistency	Rule-of-Thumb	Blows Per Foot[1] (N value)[2]	Penetrometer (tons/ft^2)
Very Soft	Core (height = twice diameter) sags under own weight	0 – 1	0.0-0.25
Soft	Can be easily pinched in two between thumb and forefinger	2 – 4	0.26-0.49
Firm (Medium Stiff)	Can be imprinted easily with fingers	5 – 8	0.5-0.99
Stiff	Can be imprinted with considerable pressure from fingers	9 – 15	1.0-1.99
Very Stiff	Barely can be imprinted by pressure from fingers	16 – 30	2.0-3.99
Hard	Cannot be imprinted by fingers	> 30	4.0+

Notes:
1) Blows as measure with a 2-inch outer diameter (OD), 1 3/8-inch inner diameter (ID) sampler driven 1 foot by a 140-pound hammer falling 30 inches. See Standard Methods for Penetration Test and Split-Barrel Sampling of Soils, ASTM D1586-99.
2) N value is the sum of the blows from 6 inches to 12 inches and from 12 inches to 18 inches in the 2-foot sample.

ATTACHMENT C
RELATIVE DENSITY OF COHESIONLESS SOILS

RELATIVE DENSITY OF COHESIONLESS SOILS

Consistency	Rule-of-Thumb	Blows Per Foot (N value)[2]
Very Loose	Easily penetrated with a ½-inch diameter steel rod pushed by hand	0 - 4
Loose	Easily penetrated with a ½-inch diameter steel rod pushed by hand	4 - 10
Medium Dense	Easily penetrated with a ½-inch diameter steel rod driven with a 5-pound hammer	11 - 30
Dense	Penetrated a foot with a ½-inch diameter steel rod driven with a 5-pound hammer	31 - 50
Very Dense	Penetrated only a few inches with a ½-inch diameter steel rod driven with a 5-pound hammer	> 50

Notes:

1) Blows as measure with a 2-inch outer diameter (OD), 1 3/8-inch inner diameter (ID) sampler driven 1 foot by a 140-pound hammer falling 30 inches. See Standard Methods for Penetration Test and Split-Barrel Sampling of Soils, ASTM D1586-99.
2) N value is the sum of the blows from 6 inches to 12 inches and from 12 inches to 18 inches in the 2-foot sample.

ATTACHMENT D
CRITERIA FOR ESTIMATING MOISTURE CONTENT OF SOILS

CRITERIA FOR ESTIMATING MOSITURE CONTENT OF SOILS

Adapted from USACE EM 1110-1-1804 and ASTM D 2488-06

Term	Description of Relative Moisture
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, no visible water
Wet	Fine grained: well above optimum water content Coarse grained: visible free water
Saturated	Water is dripping from sample, usually encountered below water table

ATTACHMENT E
STANDARD SOIL DESCRIPTORS

STANDARD SOIL DESCRIPTORS

Grain Size Terminology		
Soil Type		**Diameter**
Boulders		12-inches or greater
Cobbles		3- to 12 inches
Gravel	Coarse	0.75-inch to 3 inches
	Fine	0.19-inch to 0.75-inch
Sand	Very Coarse	1 mm to 2 mm
	Coarse	0.5 mm to 1 mm
	Medium	0.25 mm to 0.5 mm
	Fine	0.06 mm to 0.25 mm
Silt		0.004 mm to 0.06 mm
Clay		Less than 0.004 mm

Notes:
1) mm = millimeter
2) Based on Wentworth Grain Size Scale for Sediment (Wentworth 1922).
3) This terminology can also be used to describe clast size in rock cores.

Estimated Plasticity for Silt and Clay Content		
Thread Diameter (inches)	**Plasticity Index (PI)**	**Identification**
1/4	0	Silt
1/8	5 – 10	Clayey Silt
1/16	10 – 20	Clay and Silt
1/32	20 – 40	Silty Clay
1/64	40	Clay

Relative Proportions of Components	
Descriptive Term	**Percent**
Trace	1 – 10
Little	11 – 20
Some	21 – 30
And	30 – 50

Adapted from ASTM D2488-06

STANDARD DESCRIPTORS – VISUAL OBSERVATIONS OF NAPL

Descriptive Term	Definition
No Visible Evidence	No visible evidence of oil on soil or sediment sample
Sheen	Any visible sheen in the water on soil or sediment particles or the core
Staining	Visible brown or black staining in soil or sediment; can be visible as mottling or in bands; typically associated with fine-grained soil or sediment
Coating	Visible brown or black oil coating soil or sediment particles; typically associated with coarse-grained soil or sediment such as coarse sand, gravels, and cobbles.
Oil Wetted	Visible brown or black oil wetting the soil or sediment sample; oil appears as a liquid and is not held by soil or sediment grains

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE NO. SAS-05-03

WELL INSTALLATION Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the installation of monitoring wells, observation wells, and recovery/injection wells as described in the Site-Specific Work Plan, or as otherwise specified. Monitoring and observations wells are installed to 1) determine depth to groundwater and monitor fluctuations in groundwater elevation, 2) determine and monitor the depth and thickness of free-phase products (if present), 3) obtain groundwater and/or free-phase product samples for laboratory analysis, and 4) facilitate aquifer characterization. Recovery wells are installed to conduct testing and operation of systems for groundwater pumping, free-phase product recovery, and aquifer injection.

2.0 EQUIPMENT AND MATERIALS

Field personnel shall use the well construction equipment and materials required by the Site- Specific Work Plan, or as otherwise specified.

3.0 HEALTH AND SAFTEY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

4.1 General requirements

Well installation procedures should meet regulatory agency requirements. In addition, licensing and/or certification of the driller may be required. A trained supervising technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist) should be present during well installation to document the subsurface stratigraphy and construction details for each well.

The well designs should meet two basic criteria: 1) groundwater and/or other fluids (e.g. free-phase product) must move freely into the well, and 2) vertical migration of surface water or undesired groundwater to the well intake zone must, to the extent possible, be eliminated. In addition to these criteria, factors that influence the location of wells should be considered and include the following:

- Project objectives of the Site-Specific Work Plan;
- Data Quality Objectives outlined in the Quality Assurance Project Plan (QAPP);
- Location of facilities and/or source areas to be monitored;
- Groundwater gradient;
- Location of aboveground and underground utilities and manmade features; and
- Accessibility to desired well location sites.

4.2 Well Installation Materials Selection

Materials used in the construction of wells must remain essentially chemically inert with respect to free-phase products and dissolved contaminants in the groundwater for the duration of the investigation period remedial action.

The most commonly used well construction materials are PVC and stainless steel. PVC is the least expensive and easiest material to use. It is generally believed that PVC does not decompose in contact with groundwater containing low concentrations of organics. Stainless steel is chemically inert, provides greater structural strength, and its use may be advantageous for large-diameter wells or groundwater containing high concentrations of organics or free-phase products. Teflon casing is chemically inert but is very expensive.

Well casing and screen are available in threaded or unthreaded sections and typically in lengths of 5, 10, and 20 feet. Threaded pipe joints may be wrapped with Teflon tape to facilitate joining and to improve the seal. Sections of casing and screen should be assembled onsite to allow inspection immediately before installation. No solvents or adhesive compounds should be used on the threaded PVC or Teflon pipe.

4.3 Well Types and Construction Specifications

4.3.1 Monitoring and Observation Wells

Monitoring and observation wells construction should be performed as outlined in the Site-Specific Work Plan or as otherwise specified. In general, the design of the wells consists of a section of slotted well casing or well screen connected to a riser pipe that extends above the ground surface. Typically, a gravel or sand filter pack is placed in the annular space between the screen and the borehole wall. A 3-foot seal composed of hydrated bentonite pellets/chips is placed on top of the filter pack. The remaining height of annulus is sealed and/or grouted to the surface with a cement, bentonite/cement, or high solid bentonite grout; this annular space will be at least 3-feet in height. A lockable protective casing is constructed over the stick-up portion of the wells. Borehole diameters will be chosen in accordance with state regulations and SSWP specification and will meet the following minimum conditions:

- The diameter of the borehole shall be at least 4 inches greater than the inside diameter of the well casing, unless hollow stem augers are utilized.
- The inside diameter of hollow stem augers should generally be at least 2-¼ inches greater than the inside diameter of the well casing and screen.
- These annular clearances facilitate the placement of the filter pack and grout around the outside of the well screen and casing.

The screens for water table observation wells, typically 10 to 15 feet long, are installed with the center of the screen set at the level of the water table to monitor seasonal fluctuation of the water table. Monitoring screens for wells constructed below the water table, typically 5 feet long, are installed at the chosen monitoring elevation as specified in SSWPs. This SOP discusses stick-up well construction; however, flush-mount well construction may also be used as outlined in the Site-Specific Work Plan or otherwise specified.

4.3.2 Recovery/Injection Wells

Construction specifications for recovery/injection wells can vary based several factors including, but not limited, to 1) the type(s) of recovery/injection to be performed, 2) engineering evaluation objectives, 3) data quality objectives, and 3) site geology. Recovery/injection wells should be constructed as outlined in the Site-Specific Work Plan, or otherwise specified.

4.4 Borehole Advancement

4.4.1 General

Boreholes used to install wells should be drilled with the following objectives:

- To provide geological data on subsurface conditions, namely stratigraphy, occurrence of groundwater, and depth to bedrock;
- To obtain representative disturbed or undisturbed samples for identification and laboratory testing; and
- To install wells.

Prior to drilling, the following steps must be taken:

- Obtain permits from appropriate local, state, and/or federal agencies. If there is a fee for permits, drilling subcontractors usually include this as part of their fee.
- Notify (verbally or in writing) the appropriate local, state, and/or federal authorities, as appropriate, in advance of the date that drilling and installation is scheduled to begin;
- Perform a subsurface utility clearance, as outlined in SOP ENV-05-01, at all planned drilling locations;
- Prepare and implement field health and safety procedures as outlined in the HASP(s); and
- Make provisions for containment, storage, and disposal of all cuttings, drilling fluids, discharge water, and other refuse generated during well installation. Note: Permitting and waste characterization may be necessary prior to disposal activities.

4.4.2 Selection of Drilling Method

Drilling methods should be selected based on the following factors:

- The expected nature of the subsurface materials to be encountered in the boring;

- Site accessibility, considering the size, clearance, and mobility of the drilling equipment;
- Availability of drilling water and the acceptability of drilling fluids (e.g., bentonite based drilling mud) in the well;
- Diameter and depth of the well desired, including consideration of the need to set casing to prevent commingling of different transmissive zones; and
- The nature and effects of contaminants expected during the drilling.

5.0 MONITORING AND OBSERVATION WELL INSTALLATION

5.1 Well Components

Typical well components in general order of placement are as followings:

1. Surface casing (if used);
2. Well casing;
3. Screen(s);
4. Filter pack (gravel or sand pack)
5. Filter pack seal (fine sand; and bentonite seal when grout is placed as the annular seal);
6. Annular seal (bentonite chips or grout);
7. Well head protector casing; and
8. Well head apron and guard posts.

Surface casing, if needed, should be installed during borehole advancement for sealing the ground surface and subsurface transmissive zones not desired to be intercepted by the well from the borehole. Surface casing may also be needed to provide lateral support for loose unconsolidated formations that may slough into or collapse around the borehole during drilling or well installation. Casing may be extended in a telescopic fashion to permit casing through intermittent transmissive zones at greater depths to limit casing size and cost requirements.

The well casing is the primary conduit to the desired borehole interval to be monitored. It serves to seal off other stratigraphic zones from the groundwater inside the well and provides unobstructed access to the well screens. The well casing extends from the top of the well screen to either above or flush with the ground surface. It is typically a single-walled pipe, flush-threaded, of the smallest diameter to facilitate sampling equipment and to support its own weight during installation.

Screens are perforated or slotted sections of casing typically of the same size and material as the well casing. The purpose of the well screen is to allow water and/or other fluids (i.e., product) to enter the well easily while preventing entry of large amounts of sediment. The slot size of the well screen is usually determined based on selection of the filter pack material. Both are commonly related to the grain size analysis of the formation material. Methods of determining appropriate screen slot size are listed in the EPA Manual of Water Well Construction Practices (USEPA 1976). Typically, 10-slot (0.010 inch slot width) or 20-slot (0.020 inch slot width) screens are used. The length of the screen depends on the sampling objective, water level fluctuations, product thickness, and thickness of the transmissive zone of the formation.

A filter pack consisting of clean silica sand or pea gravel is placed in the annular space extending to at least 2 feet above the top of the screen. Filter pack grain size, sand or pea gravel, is determined based on the well screen slot size selected and the nature of the surrounding native material. The filter pack will stabilize the aquifer formation, minimize the entry of fine-grained material into the screen, permit use of screens with different sizes of slot, and will increase the effective well diameter and water collection zone. A filter pack seal, consisting of at least 2 feet of fine sand, will be placed on top of the filter pack to prevent the intrusion of overlying grout material.

For wells with that utilize grout as an annular space seal, an additional filter pack seal, consisting of bentonite pellets or chips, should be installed above the fine-sand filter pack seal to prevent the intrusion of overlying grout material into the filter pack. The bentonite pellets or chips should be slowly poured from the top of the borehole to prevent bridging. At least 3 feet of bentonite seal should be placed on top of the fine-sand filter-pack seal. If the bentonite seal is above the saturated zone, the bentonite pellets or chips should be hydrated with distilled water before grouting the remaining annular space. The source and volume of water used must be recorded in field notes. The hydrated pellets or chips should be allowed to set for a minimum of 15 minutes. Bentonite chips are preferred over pellets or balls when the seal is below the water table because the chips hydrate less rapidly and bridging is less common.

The annular space above the bentonite seal should be grouted with cement high-solids bentonite, bentonite/cement grout, or bentonite chips, up to 30 inches below the ground surface and shall be at least 2 feet in thickness. The primary purpose of grouting is to minimize the vertical migration of water to the groundwater intake zone and to increase the integrity of the well casing.

A 30 inch concrete plug should be installed above the annular grout, when the surface seal is less than 5-feet in depth. The concrete plug is used to set the protective well cover and to prevent frost heave of the concrete pad or apron. The concrete apron should be at least 3.5 inches thick, and it should be sloped to allow water drainage away from the well.

A protective cover with a locking cap should be installed after the well has been set. This cover will protect the exposed well casing from damage and will provide security against tampering with the well. The protective cover typically consists of a steel pipe or box around the well casing. The protective cover is set at least 5 feet into the surface seal and may be reduce to 2 feet if a flush-mount well cover is placed or a shorter protective cover is required to ensure well construction space for a 2 foot minimum annular space seal.. Weep holes (approximately ¼-inch diameter) may be drilled into the base of the protective cover above the concrete apron to allow drainage. Alternatively, one to two inches of fine-grained sand may be placed at the base of the flush-mounted protective cover to facilitate drainage.

Well-head aprons and guard posts, when used, provide additional surface protection to the well and are generally used for wells in high traffic areas or where a more permanent structure is desired.

5.2 Installation Procedures

The decision to install a well at a particular location is often decided in the field upon completion of the boring and subsurface sampling. If the borehole diameter is not sufficient to install a well, either the borehole should be reamed using a larger diameter auger or a new borehole should be drilled. The new borehole should be at least 5 feet away from the initial boring. The initial soil boring should be abandoned according to the procedures outlined in SOP ENV-05-05. If a well is not installed, the boring should be abandoned in accordance with SOP ENV-05-05.

Over-drilling generally should not be conducted to provide room for a well sump or additional filter pack material at the bottom of the borehole beneath the well casing. However, for wash rotary boreholes drilled in soft or highly plastic sediments, loose cuttings may fall to the borehole bottom after backwashing. In this case, it may be necessary to install a 2-foot layer of sand or gravel at the bottom of the boring to provide a firm base on which to set the well assembly to limit settling of the well casing and screen under its own weight.

For mud rotary boreholes, excess drilling fluids should be flushed from the borehole before installing the filter pack and grout seal. This can be accomplished by one or both of the following means:

- Flush the well using the drilling equipment by pumping clean water down the drill pipe without circulating the returned fluid. This should be accomplished at low pump pressure and with care to avoid scouring or fracturing of the formations. The source and volume of water added to the well must be recorded in field notes.
- Insert casing and screens with a backwash valve on the bottom end, and then flush the borehole via the well casing at low pressures. The backwash valve not only provides an outlet for flushing, but also provides pressure relief so the screens are not damaged by the backwash fluid pressures.

The latter method should be conducted only if it is determined that the former is not possible, or if the drilling fluid must remain in place in order to install the filter pack.

Connect the screen and well casing while wearing latex gloves. Insert and lower the screen and well casing into the borehole in 10-foot increments. Hand-tighten connections to prevent them from leaking or becoming loose. The final section of pipe should be measured and field cut, if necessary, before connecting to allow for a stick-up of at least 2 feet. The cut end should be rasped and/or sanded smooth, taking care not to let fillings of casing material cling to the inside.

Backwash the boring, if necessary, and pour in sand or gravel to seat and support the casing and screen. Based on boring and casing diameters, determine volume of filter pack material required to place the filter approximately 2 feet above the top of the screens. Install filter pack using the following methods, as appropriate.

- Slowly pour filter material down annulus, being careful to evenly distribute the material around the casing and to avoid the material becoming packed between the sidewall and casing. Use a small-diameter pipe to dislodge packed material and to ensure adequate height and settlement of the filter pack.

- Pour filter material down tremie pipe placed between boring sidewall and casing. In this method, clean potable or distilled water should be poured in along with the sand or gravel to prevent packing within the tremie. The source and volume of water added must be recorded in field notes. The bottom of the tremie should be kept above the filter material top by at least 5 feet to permit the filter material to evenly fall around the screens. Pack the material with the tremie pipe to ensure adequate height and settlement of the filter pack.

Pour bentonite pellets or chips down the annulus on top of the filter pack. The bentonite should be placed rapidly to prevent swelling and bridging around the casing when it hydrates. The bentonite should be allowed to hydrate for at least 15 minutes before grouting.

The remaining annulus should be sealed by pumping grout via a tremie pipe from the bottom of the annular space of the borehole until the grout returns to the surface displacing all remaining drilling fluid and formation water. The bottom of the tremie pipe should not be placed within 4 feet of the bentonite seal. Grouting mixture and technique should be in accordance with Site-Specific Work Plan requirements, or as otherwise specified. Grout will typically settle 1 to 2 feet. Remove excess grout to allow 30 inches of annular space for the concrete plug or native material.

After the grout has stiffened sufficiently, install the concrete plug up to the ground surface. Set the protective cover, if possible, such that at least 2 feet of its length is embedded in the concrete below the ground surface. It should also be set such that it is not more than approximately 30 to 36 inches above the level where the sampling personnel must stand. A concrete pad approximately 3 feet in diameter and 3.5 inches thick should be formed around the base of the protective cover. The concrete pad should be sloped away from the protective cover to allow flow away from the well. Weep holes should be drilled through the protective cover nominally 1 inch above the top of the concrete apron.

The protective casing should be marked with identifying decals. A locking device should be installed to prevent unauthorized entry or vandalism of the well. The top of the well casing should be notched with a file to provide a reference point in which to measure water and/or product levels. The elevation of the top of the well casing (reference point) and ground surface at the well should be surveyed relative to a benchmark. The location of the well should also be surveyed in reference to the site coordinate system as required by the Site-Specific Work Plan, or as otherwise specified.

Develop well within 24 to 72 hours following well installation according to the well development procedures outlined in ENV-05-04.

6.0 DOCUMENTATION

Documentation of well installation should be the responsibility of the supervising field technician. A well completion report should be prepared after the well is installed. The Illinois Department of Public Health Well Completion Report is provided as a well completion report example in Attachment A. If the work is performed in a different state, the relevant forms must be obtained.

The drilling and well installation activities should be recorded in the field logbook and/or on the appropriate field forms. The following information should be recorded during and upon completions of every well installation:

- Project name and number;
- Well location identification;
- Date of installation and time completed;
- Drilling method, crew names, and rig identification;
- Drilling depths;
- Generalized subsurface stratigraphy;
- Total length of casing and screens;
- Depth to and length of screened intervals;
- Depth to top of filter pack;

- Depth to top of bentonite seal;
- Depth to top of grout;
- Depth of surface casing (if applicable);
- Elevation of top of well casing and ground surface; and
- Name of supervising field technician.

The driller should also prepare any state-required well completion forms in accordance with state regulatory requirements.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2004, D5092-04 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.

ASTM International, 2005, D6001-05 Guide for Direct-Push Ground Water Sampling for Environmental Site Characterization.

ASTM International, 2004, D6724-04 Guide for Installation of Direct-Push Ground Water Monitoring Wells.

ASTM International, 2004, D67-25-04 Practice for Direct-Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers.

USEPA, 1976, Manual of Water Well Construction Practices, EPA/570/9-75/001.

USEPA, 2002, Ecological Assessment Standard Operating Procedures and Quality Assurance Manual, SESD, Region 4, Ecological Assessment Branch, Athens, Georgia.

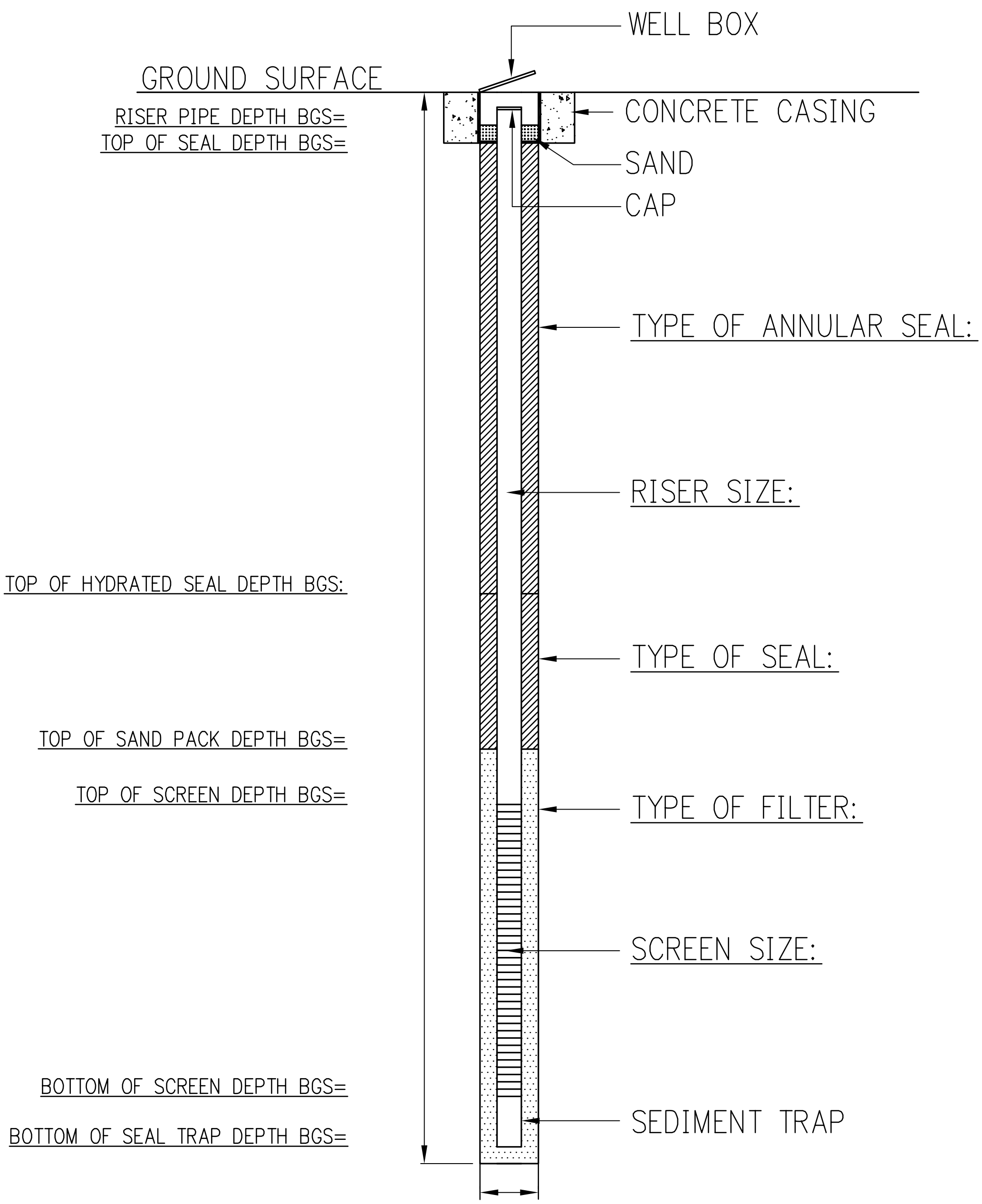
USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
WELL INSTALLATION LOGS

WELL INSTALLATION LOG

No. ________

CLIENT	COORDINATES N	PROJECT	PROJECT NO.
PROJECT LOCATION	E	TOP OF RISER ELEVATION (DATUM)	DATE
STRATUM MONITORED		LOGGED BY	
DRILLING COMPANY		APPROVED BY	



NOT TO SCALE

METHOD OF INSTALLATION:

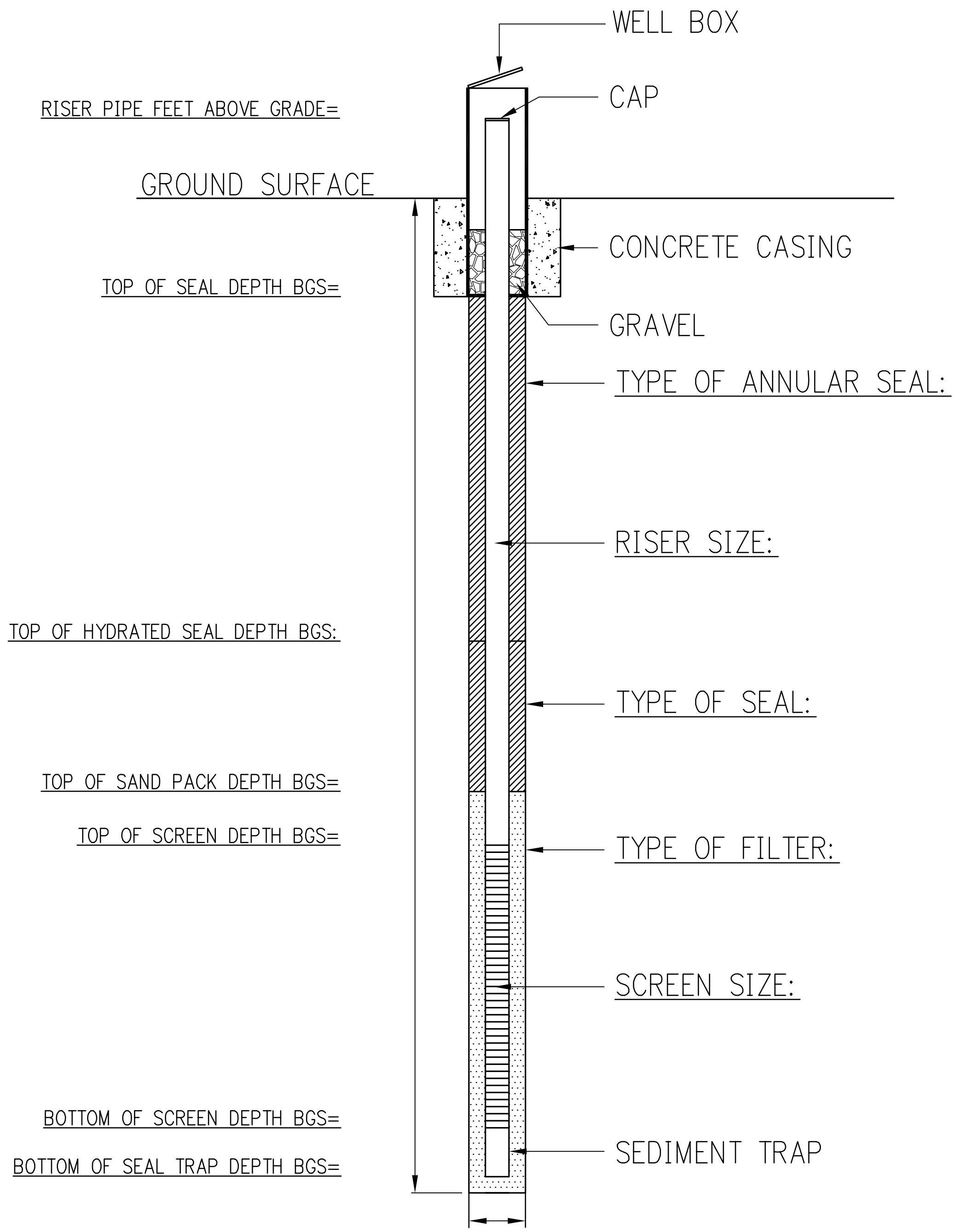
REMARKS:

I:\CAD\BMC\TEMPLATES\FLUSH MOUNT WELL LOG.NL

WELL INSTALLATION LOG

No. __________

CLIENT	COORDINATES N E	PROJECT	PROJECT NO.
PROJECT LOCATION		TOP OF RISER ELEVATION (DATUM)	DATE
STRATUM MONITORED		LOGGED BY	
DRILLING COMPANY		APPROVED BY	



NOT TO SCALE

METHOD OF INSTALLATION:

REMARKS:

Author:	**T. Gilles**	**Q2R & Approval By:**	**C. Barry**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE
NO. SAS-05-04

WELL DEVELOPMENT
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for developing wells. Well development is conducted to 1) remove drilling fluids or mudcake from the filter pack, borehole wall, and formation materials, 2) remove any loose, fine-grain, formation materials (e.g. fine sand, silt, and clay) from the filter pack and well screen to eliminate, to the extent possible, impact the integrity of groundwater and/or product samples and aquifer characterization test results, and 3) restore the natural permeability of the formation adjacent to the borehole.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials will vary by development method. Field personnel should use the equipment and materials required by the Work Plan or otherwise specified for the development method(s) selected for the project. All non-disposable equipment, including pumps, hoses, containers, and bailers, shall be decontaminated before and after introduction into wells. Equipment decontamination should be performed in accordance with SOP ENV-04-05 and/or requirements of the Site-Specific Work Plan.

3.0 HEALTH AND SAFETY WARNING

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 DEVELOPMENT METHODS

4.1 Air Lifting

The airlift method involves pumping compressed air down an eductor pipe placed inside the well casing. Due to its inert characteristic, nitrogen is the preferred gas for air lifting. Pressure is applied intermittently and for short periods causing the water to surge up and down inside the casing. Once the desired surging is accomplished, continuously applied air pressure should be used to blow water and suspended sediments upward and out of the well.

The use of standard air for well development may impact permeability of the formation surrounding the well screen and groundwater quality. Considerable care must be exercised to avoid injecting air directly through the well screen. Air can become trapped in the formation materials outside the well screen and affect subsequent chemical analyses of water samples and hydraulic conductivity measurements. The bottom of the air pipe should not be placed below the top of the screened section of casing.

Another restriction of the use of air is the submergence factor. The submergence factor is defined as the height of the water column above the bottom of the air pipe (in feet) divided by the total length of the air pipe. To result in efficient airlift operation, the submergence factor should be at least 20 percent. This may be difficult to achieve in shallow monitoring wells or wells that contain small volumes of water.

4.2 Surging or Plunging

A surge block is a round plunger with pliable edges (constructed of a material such as rubber belting) that will not catch on the well screen. Moving the surge block forcefully up and down inside the well screen causes the water to surge in and out through the screen accomplishing the desired cleaning action. The amount of pressure generated by the surging must be closely monitored to prevent cracking of the well casing or screen.

A well slug may also be used to create a surging effect through the filter pack and formation. A slug consists of a PVC rod or pipe (with capped ends) sufficiently weighted to rapidly sink in water. The slug is alternately lowered into and retrieved from the water in the casing to create a water level differential that induces flow into or out of the well to accomplish the desired cleaning action. This method is less aggressive than using a surge block. For shallow wells or wells in which the water column in the casing is small, care must be exercised when lowering the slug so as not to drive the slug into the bottom of the casing or against the screens.

4.3 Bailing or Pumping

Bailers may be used for development of low-yielding wells or wells with a significant amount of sediment (approximately 10% in the well screen) to remove excess sediment. A bailer that is heavy enough to sink rapidly through the water can be raised and lowered through the water column to produce the surging action that is similar to that caused by a surge block or well slug. The bailer, however, has the added capability of removing turbid water and fines each time it is brought to the surface. Bailers are very useful for developing shallow and slow yielding wells. As with surge blocks, it is possible to produce pressure great enough to crack PVC casing. Bailers are the simplest and least costly method of developing a well, but are time-consuming.

Pumping can be used effectively in wells where recharge is rapid. The pump may be used to back flush and overpump (at rates that exceed purging and sampling rates) water in and out of the well screen. The type and size of the pump used is contingent upon the well design. Pumps also allow removal of turbid water and fines. However, pumps are more difficult to decontaminate than a bailer is.

5.0 EXECUTION

The following procedures shall be adhered to unless well development requirements are otherwise specified in the Site-Specific Work Plan:

1. Measure the depth to groundwater in accordance with the guidelines described in SOP ENV-08-02. The standing water volume (V) in the well to be developed shall be calculated using one of the following formula in accordance with the Site-Specific Work Plan:

    Borehole Volume Calculation

    $V = nA (B - C) + CD$

    Where, n = porosity of the filter pack;
    A = height (in feet) of the saturated filter pack;

B = volume (in gallons per foot) of water in the borehole (see Table below);
C = volume (in gallons per foot) of water in the well casing (see Table below); and
D = height of standing water column (in feet) in the well.

Well Volume Calculation

V = CD

Where, C = gallons per foot of water in the well casing (see Table below); and
D = height of standing water column (in feet) in the well.

Diameter-Specific Volume Per One Foot of Casing/Borehole				
Diameter (Inches)	**Volume Per Foot of Casing/Borehole (Gallons)**		**Diameter (Inches)**	**Volume Per Foot of Casing/Boring (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

2. Measure water quality parameters immediately prior to and during well development at a minimum frequency of once per well volume removed in accordance with SOP ENV-08-03. The water quality parameters should generally include pH, specific conductance and/or actual conductivity, temperature, dissolved oxygen, and turbidity, unless otherwise specified in the Work Plan. Record water quality parameters, as well as visual turbidity and evidence of impact (e.g. free phase product, sheen, odors, etc.) observations in the field logbook and/or on the appropriate field form.
3. Remove 10 standing water volumes or the volume required to achieve water quality parameter stabilize and visual clarity is achieved, whichever is less. A well that will not yield sufficient volume must be slowly bailed or pumped, allowed to recover to within 90% of the pre-development standing water volume, and then slowly bailed or pumped a second time, with a maximum of five purge periods. The criteria for parameter stability are summarized below.

4. Increase the minimum development water volume when drilling water and/or fluids are lost prior to well development. This additional purge volume shall be at least three times the volume of lost fluid.

Water Quality Parameter	Stability Criteria[1]
pH	+/- 0.1 Std. Units
Temperature	+/- 0.1°C
Specific Conductance or Actual Conductivity	+/- 3% microsiemens/cm
Dissolved Oxygen	+/- 0.3 milligrams/Liter
Turbidity	<10 NTUs or + 10% when turbidity is greater than 10 NTUs and/or visually clear water

5. Containerize development water in approved, labeled containers (e.g. 55-gallon drums, polyethylene storage tanks, baker tanks, etc.) as required by the Site-Specific Work Plan or otherwise specified.

6.0 DOCUMENTATION

Well development activities will be documented in the field logbook and/or appropriate field form included in Appendix B of the FSP, describing the procedures used and any significant occurrences that are observed during development such as apparent recharge rates in the well, condition of the groundwater, and organic vapor readings. Well development data including the depth to static water, standing water volume in the well, standing water volume calculations, total volume of water removed, number of well volumes removed, and water quality parameters will be recorded in the field logbook and/or on the field activity form (Appendix B of the FSP).

7.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 1992, Monitoring Well Development Guidelines for Superfund Project Managers, Office of Solid Waste and Emergency Response, http://www.epa.gov/tio/tsp/download/welldevelp.pdf.

USEPA, 2002, Ecological Assessment Standard Operating Procedures and Quality Assurance Manual, SESD, Region 4, Ecological Assessment Branch, Athens, Georgia.

[1] USEPA, May 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, Revision 2, EPA/542/S-02/001.

USEPA, May 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, Regions 5 and 10, EPA/542/S-02/001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE NO. SAS-05-05

BOREHOLE AND WELL ABANDONMENT Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for borehole and well abandonment. When boreholes and wells are no longer needed to complete project goals and objectives, they must be properly abandoned to prevent them from acting as a conduit for migration of contaminants from the ground surface to the water table or between transmissive zones.

2.0 EQUIPMENT AND MATERIALS

Equipment and materials may vary based on borehole and well accessibility and depth and well construction. Field personnel should use the equipment and materials required by the Site-Specific Work Plan or otherwise specified for the project. All non-disposable equipment shall be decontaminated before and after introduction into borehole or well. Equipment Decontamination should be performed in accordance with SOP SAS-04-05 and/or requirements of the Site-Specific Work Plan.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Borehole and well abandonment procedures should meet applicable regulatory agency requirements. In addition, licensing and/or certification of the driller may be required. A trained supervising technician (e.g. geologist, hydrogeologist, engineer, or environmental scientist) should be present during well abandonment to document the activities. The supervising technician should complete and submit a well abandonment form, if required, to the appropriate regulatory agency. Attachment A contains the Illinois Department of Public Health Water Well Sealing Form as an example. If wells are abandoned in other states, the relevant forms and procedures shall be implemented.

5.0 EXECUTION

Unless otherwise specified in the Site-Specific Work Plan, the following guidelines shall be followed. The preferred well abandonment method is to completely remove the well casing and screen from the borehole. This may be accomplished by auguring with a hollow-stem auger over the well casing down to the bottom of the borehole, thereby removing the grout, bentonite seal, and filter pack from the hole. The well casing shall be then removed from the borehole with the drill rig. The remaining borehole and boreholes not utilized for the construction of a monitoring well, is subsequently backfilled with the appropriate backfill material. The backfill material (e.g. bentonite, Portland cement, etc) shall be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method) to within 30 inches of the ground surface. . The annular space shall be filled with bentonite chips, grout, or granules to at least 30 inches bgs unless land use requires a design modification to use native material (gravel, soil, etc.) or material in adjacent areas (asphalt, concrete, etc.) to bring the former well location to grade. If the area has heavy traffic and/or construction use, the location will be barricaded until the plug has cured or concrete plug recessed below ground surface will be used to maintain the surface seal. This abandonment method can typically be accomplished on small-diameter wells (4-inches or less in diameter) without much difficulty.

The use of hollow-stem augers for casing removal on large-diameter wells (diameter greater than 4-inches) typically ranges from very difficult to almost impossible. On large-diameter wells with little to no grout, a drill stem with a tapered wedge assembly or solid-stem auger should be used to ream out the borehole and extract the well materials. Wells that are badly corroded and/or have thickly grouted annular space have a tendency to twist and/or break off in the borehole. Should this occur, the well would be grouted with the remaining casing left in the borehole. In this case, the well and borehole shall be pressure grouted by placing a tremie pipe in bottom of the well casing, which will be the well screen or bottom sump area below the well screen. The pressurized grout will be forced out through the well screen into the filter pack and up the inside of the well casing sealing holes and breaks that are present. The tremie pipe shall be retracted slowly as the grout fills the casing. The annular space shall be filled with bentonite chips, grout, or granules to at least 30 inches bgs. The well casing shall then be cut off at least 30 inches below. Native material (gravel, soil, etc.) or material in adjacent areas (asphalt, concrete, etc.) may be used to bring the former well location to grade. If the casing has been broken off below the surface, the grout shall be tremied to within 30 inches of the ground surface and then finished similar to the surrounding features.

Brittle polyvinyl chloride (PVC) well casings may be more difficult to remove from the borehole than stainless-steel casings. If the PVC well casing breaks during removal, the borehole shall be cleaned out by using a drag bit or roller cone bit with the wet rotary method to grind the casing into small cuttings that will be flushed out of the borehole by the drilling fluid. Another method is to use a solid-stem auger with a carbide auger head to grind the PVC casing into small cuttings that will be brought to the surface by the rotating flights. After the casing materials have been removed from the borehole, the borehole shall be cleaned out and pressure grouted with the approved grouting materials. As previously stated, the borehole shall be finished with a concrete surface plug or site-specific surface restoration material with adequate surface protection, unless otherwise directed or required by the Site-Specific Work Plan.

6.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2005, D5299-99 (2005) Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
BOREHOLE / WELL ABANDONMENT FORM

BOREHOLE / WELL ABANDONMENT FIELD FORM

PROJECT INFORMATION

Site: ____________ Client: ____________

Project Number: ____________ Task #: ____________ Start Date: ____________ Time: ____________

Field Personnel: ____________ Finish Date: ____________ Time: ____________

GENERAL INFORMATION

Ownership (Controlling Party): ____________

Street Address: ____________

City: ____________

County: ____________

State: ____________ Zip: ____________

Township: ________ Range: ________ Section: ________

________ 1/4 of the ________ 1/4 of the ________ 1/4

If Known, Latitude: ________ Longitude: ________

If Known*, Northing: ________ Easting: ________

*Coordinate System: ____________

Reason for Abandonment:

Permit Number (If applicable): ____________

BOREHOLE / WELL INFORMATION

Borehole / Well ID: ____________

Unique Well ID:

Installation Date: ____________

☐ Borehole

☐ Monitoring Well

☐ Water Well

Attach Well Completion Report, if available

☐ Other (specify): ____________

Construction Type:

☐ Drilled ☐ Driven (Sandpoint)

☐ Other (specify): ____________

Formation Type:

☐ Unconsolidated Materials ☐ Bedrock

Borehole/Well Details:

Borehole Diameter: ________ Inches

Total Borehole Depth: ________ FT BGS

Casing Diameter: ________ Inches ☐ Not Applicable

Total Casing Depth: ________ FT BGS ☐ Not Applicable

Depth to Water: FT BGS ☐ Not Encountered

SEALING INFORMATION

Pump & Piping Removed? ☐ Yes ☐ No ☐ Not Applicable

Liner(s) Removed? ☐ Yes ☐ No ☐ Not Applicable

Screen Removed? ☐ Yes ☐ No ☐ Not Applicable

Entire Casing Removed? ☐ Yes ☐ No* ☐ Not Applicable

If No, Upper 2 feet Removed? ☐ Yes ☐ No

Method of Sealing Material Placement:

☐ Conductor Pipe - Gravity ☐ Tremie Pipe - Pumped

☐ Screened & Poured ☐ Other (specify): ____________

Sealing Material Rose to Surface? ☐ Yes ☐ No

Material Settled After 24 Hours? ☐ Yes* ☐ No

*If Yes, Was Hole Re-Topped? ☐ Yes ☐ No

Sealing Material Used	From	To	Volume/Quantity
	Surface		

SEALING WORK PERFORMED BY

Individual's Name: ____________

License Number:

Company Name: ____________

Street Address: ____________

City: ____________ State: ________ Zip: ________

SOP SERIES SAS-06

SOIL SAMPLING AND MEASUREMENT PROCEDURES

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE NO. SAS-06-01

SOIL SAMPLING FOR CHEMICAL ANALYSES AND GEOTECHNICAL TESTING Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for obtaining surface and subsurface soil samples as stated in the Site-Specific Work Plan or as otherwise specified. Soil sampling is conducted for the purpose of chemical analyses and geotechnical testing to evaluate surface and subsurface conditions.

2.0 EQUIPMENT AND MATERIALS

In addition to materials provided by a subcontractor, the field personnel should have the following:

- Sample bottles/containers and labels;
- Sample cutting/extracting equipment (scoops, trowels, shovels, hand augers);
- Field logbook and/or the appropriate field form(s);
- Depth and length measurement devices with 0.01-foot measurement units;
- Camera;
- Stakes and fluorescent flagging tape;
- Decontamination materials;
- Coolers and ice;
- Chain of custody forms;
- Custody seals;
- Gallon size sealable plastic bags;
- Clear plastic packaging tape; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 SAMPLE TYPE, METHOD, AND EQUIPMENT SELECTION

4.1 Preparation

Site-Specific Work and/or Field Sampling Plans (FSP) which involve soil sampling shall be carefully conceived with respect to data quality objectives (DQOs) and cost effectiveness. Soil samples shall be strategically located to collect a representative fraction of soils with the minimum number of samples. To facilitate complete and successful sampling efforts by minimizing uncertainties with respect to site characterization the following factors shall, at a minimum, by considered during preparation activities:

- Project goals and DQOs;
- Location and duration of historical property uses (if available);
- Location and duration of current property uses;
- Chemical properties of contaminants of potential concern (COPCs);
- Anticipated location(s) of COPCs (e.g. surface, subsurface, etc.);
- Anticipated geologic conditions including presence and elevation of groundwater;
- Site accessibility; and
- Results of previous site reconnaissance and investigations (if available).

4.2 Field Considerations

Field personnel shall review and be familiar with Site-Specific Work and/or FSPs prior to commencement of sampling activities. Field personnel will also facilitate complete and successful sampling efforts by calibrating and operating field instruments/meters used for sample media screening in accordance with SOP ENV-02-01. In addition, field personnel shall be cognizant of the following during investigative activities:

- Indications of COPCs not previously anticipated;
- Evidence (e.g. visual, olfactory, etc.) of COPCs in locations not previously anticipated;
- Geologic conditions not anticipated;
- Changes in site accessibility; and
- Meteorological conditions (e.g. high humidity, rain, etc.) that have the potential to negatively impact operation and performance of field screening instruments, and sample quality.

Field personnel shall notify the Project Manager when field conditions and observations deviate from those anticipated during sampling event preparations. The Project Manager shall approve any deviation from the Work and/or Sampling Plans prior its occurrence. Deviations and approval to deviate from Site-Specific Work and/or FSPs shall be documented in the field logbook and/or on the appropriate field form by the field personnel.

5.0 SAMPLE TYPES

5.1 Grab Samples

Grab samples are collected to identify and quantify compounds at a specific location or interval. Grab samples are limited in areal and vertical extent. A grab sample shall be comprised of no more than the minimum amount of soil necessary to obtain the volume of sample dictated by the required sample container.

5.2 Composite Samples

Composite samples are a mixture of a given number of sub-samples/aliquots and are collected to characterize the average composition of a given surface area, vertical interval, etc. The number of sub-samples/aliquots forming a composite sample shall remain consistent with the context of the investigation. The number and pattern for collection of sub-samples/aliquots within a grid, interval, etc. shall be selected based on project goals and DQOs and shall not change. Composite sampling is associated with two potential interferences:

1. Low concentrations, if present in individual sub-samples/aliquots, may be diluted to the extent that the total composite concentration is below the analytical reporting limits.
2. Sub-samples/aliquots that are predominantly moist clay can be difficult to composite to produce a homogenous mixture. The resulting sample, as represented by the portion selected by the analytical chemist, may not be representative of an average of all the sub-samples/aliquots.

6.0 SAMPLING METHOD

6.1 Random

Random sampling removes the subjective collection of samples based on personal judgment. Soil samples are typically selected from all investigation area(s) when a suspected area of contamination is unknown. Generally, this method is utilized with site screening investigations when there is no strong indication of contamination or distinct depositional areas are present that provide excellent screening samples.

6.2 Biased

Biased sampling involves the collection of samples based on evidence of contamination (e.g. staining, stressed vegetation, elevated field screening results, etc.). Background and control samples are also considered biased, since they are collected from locations anticipated to be impacted or expected to be clean.

6.3 Grid-Based

Grid-based sampling involves the systematic collection of samples based on the size and configuration of an area. This approach is used to characterize the presence and distribution of contaminants and is commonly utilized for large areas. Grid size will be selected during the preparation phase and shall be specified in the Work or Sampling Plan. Common grid sizes shall be developed based on the size and configuration of the area, project goals, and DQOs. It may be appropriate and acceptable to integrate several different grid sizes in a single investigation.

When a Site is extremely large (typically over several acres), it may not be practical and cost-effective to consider sampling every grid. In this case, it will be necessary to statistically select a sub-set of the total number of grids in order to reduce the number of samples collected. On the other hand, it may be more appropriate to use relatively inexpensive screening level analytical techniques to define the areas that will need to be sampled and analyzed for a higher level of data quality. In all cases, grid points shall be located using a site survey and shall be semi-permanently marked to facilitate relocating the sample locations for subsequent sampling.

7.0 SAMPLING EQUIPMENT AND PROCEDURES

7.1 Manual Sampling

In general, hand sampling using manually operated equipment is a quick and inexpensive sampling technique for shallow depths when precise data or high quality control is generally not required. The most common hand-operated samplers are hand augers, plugs, tubes, split-barrel or fixed piston samplers that are pushed or driven by hand.

Hand augers are easily used at depths less than 10 feet. The most commonly used, manually-operated hand augers include the ship, closed-spiral, and open-spiral augers. In operation, a hand auger shall be attached to the bottom of a length of pipe that has a cross-arm at the top. The hole shall be drilled by turning this cross-arm at the same time the operator presses the auger into the ground. As the auger is advanced and becomes filled with soil, it shall be taken from the hole, and the soil shall be removed. Additional lengths of pipe will be added as required to reach the sampling depth as required by the Site-Specific Work Plan or otherwise specified. Care shall be taken to prevent (to the extent possible) mixing of the soil from upper portions of the hole with lower samples. This is most likely to be a problem when augers are used to advance a hole and obtain samples from soil cuttings.

Pushed samplers can be used to obtain samples within about 3 feet of the surface or, with appropriate extensions, ahead of an augured hole. The sampler will be pushed to the desire depth by the operator. The pusher sampler shall be used with extension(s) and/or in combination with a hand auger to reach sample depths greater than 3 feet below ground surface. When the sampler becomes filled with soil, it shall be taken from the hole and the soil removed. Care shall be taken to prevent mixing of soil from upper portions of the hole with lower samples.

Because of the unpredictable operations that may have been used at many uncontrolled waste sites, sampling devices will never be forced into an abruptly hard material. The stiffness may be a natural lithology change, a rock ledge or cobble, or a buried drum. If resistance is encountered while auguring or pushing a sampler, the procedure will be stopped. The depth at which resistance was met should be recorded into the field logbook and/or on the appropriate field form.

7.2 Split-Spoon Sampler

The split-spoon sampler is a thick-walled steel tube that is split lengthwise. A cutting shoe is attached to the lower end of the barrel; the upper end contains a check valve and is connected to the drilling rods. When a boring is advanced to the point that a sample is to be taken, drill tools are removed, and the sampler is lowered into the hole attached to the bottom of the drill rods.

The split-spoon sampler is driven by a 140-lb hammer falling 30 inches. The split-spoon sampler shall be driven 18 inches into the ground or until 50 blows have been applied in a 6-inch increment, a total of 100 blows have been applied, or there is no observable advance of the sampler after 10 successive blows. The effort taken to drive the sampler shall be recorded at 6-inch intervals and the sampler shall be removed from the boring. The density of the sampled material shall be determined by summing the blow counts for the second and third 6 inches of penetration (“standard penetration resistance” or “N-value”) per ASTM D 1586-99. Only disturbed samples are obtained using this procedure.

The standard size split-spoon sampler is 2-inch outside diameter (OD), $1^{3}/8$-inch inside diameter (ID), and 24 inches long. When soil samples are taken for chemical analysis, a 2- or 2½-inch ID sampler shall be used to provide a larger volume of material, but cannot be used to calculate strength or density properties as stated in the ASTM D 1586-99 test method.

Upon retrieval, excess soil or drilling fluid shall be rinsed or wiped from the sampler’s exterior, the cutting shoe removed, and sampler broke open into the two halves. The sample shall be logged and classified in accordance with SOP ENV-05-03. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated. The split-spoon sampler shall be decontaminated between sample intervals in accordance with SOP ENV-04-05.

Liner tubes or sleeves may be incorporated in certain samplers to contain samples temporarily. The liner tubes may be constructed from brass, plastic, or other inert materials used to store and transport the samples. If a sample is to be stored in the liner tube, the tube ends shall first be covered with Teflon film, followed by a plastic slip cap. On each sample end, the Teflon film shall be trimmed, and the cap sealed with vinyl tape to the liner tube. If the sampler is not to be stored in the liner, it will be transferred from the sampler to the appropriate sample container using either the liner tube or a stainless steel or plastic spoon or spatula.

When taking samples for geotechnical testing, the disturbed soil samples shall be removed from the sampler are placed in a sealable glass jar or other containers approved by the geotechnical laboratory and labeled to indicate the project name and number, boring number, sample number, and depths at top and bottom of the sample interval. This information shall be marked on the jar lid using a permanent marker. Other information required by the Site-Specific Work and/or FSP shall be recorded in the field logbook and/or on the appropriate field form.

7.3 Continuous Core Barrel Sampler (CME-Type)

A continuous core barrel sampler (CME-Type) is 5 feet long and fits inside the lead auger of the hollow-stem auger column. The sampler retrieves a 5-foot section of partially disturbed soil samples. The sampler assembly consists of either a split barrel or solid barrel that can be used with or without liners. The split-barrel sampler is most commonly used because it is easier to access and remove the core samples. The core barrel sampler takes the place of the pilot bit, thereby reducing sampling time. The sampler is most efficient in clays, silts, and fine sand.

The sampler shall be attached to the drill rod and locked in-place inside the auger column. The open end of the sampler shall extend a short distance ahead of the cutting head of the lead auger. The hollow-stem auger column shall be advanced 5 feet while the soil enters the non-rotating core sampling barrel. The barrel shall then be retrieved with the drill rod, and the core extruded from the sampler. The sample shall be logged and classified in accordance with SOP ENV-05-03. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated in accordance with SOP ENV-04-05.

7.4 Thin-Walled (Shelby) Tube Samplers

Thin-walled samplers, such as a Shelby tube, should be used to collect relatively undisturbed samples of soil from borings. The samplers are constructed of steel tubing about 1 to 3 mm thick, depending upon its diameter. The lower end has a tapered cutting edge. The upper end is fastened to a sample head adapter with a check valve to help hold the sample in the tube when the tube is being withdrawn from the ground. Thin-walled tube samples are obtained by any one of several methods including pushed-tube, Pitcher sampler, Denison sampler, and piston sampler methods.

In obtaining pushed-tube samples, the tube shall be advanced by hydraulically pushing it in one continuous movement with the drill rig. At the end of the designated push interval and before lifting the sample, the tube shall be twisted to break the bottom of the sample. The tube shall be retrieved from the boring using the drill rig. One of two methods shall be employed for handling the sample once it is retrieved from the boring:

1. Extruding the sample from the sample tube in the field using an extruding device on the drilling rig, and subsequently handling and containerizing the specimen at the drilling site.
2. Leaving the sample in the sampling tube, preparing it for transportation, with subsequent extrusion and handling elsewhere.

A hydraulic extruder shall be used in all cases to minimize disturbance. To extrude the sample from the tube, the tube shall be connected to the extruding device in the appropriate fashion for that type extruder. Some extruding devices push the sample in the same direction that the sample entered the tube, pushing out the top, while others push it out the bottom. It does not matter for environmental sampling, but the orientation of the sample shall be known and kept clear by the sampling personnel. The sample shall be caught on a split section of PVC pipe lined with polyethylene sheeting or aluminum foil. Waxed paper will not be used. Drilling fluids shall be carefully poured off and cuttings or slough material at the top end of the sample raked away, leaving only the true sample interval. The sample shall be transferred to a cutting board by lifting with the poly/sheeting or aluminum foil and length of the sample shall be measured. The sample shall be logged and classified in accordance with SOP ENV-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampler tube shall then be decontaminated in accordance with SOP ENV-04-04.

Shelby tubes will not be reused for subsequent sampling intervals. A sufficient number of decontaminated sampling tubes shall be brought to the sampling location to complete the required scope of work and protected from being contaminated before use.

7.5 Cuttings or Wash Samples

Drill cuttings or wash samples may be taken as the boring is advanced. A stainless steel or plastic scoop shall be used to obtain a sample from the cuttings pile. The shovel used by drilling personnel to move cuttings shall be stainless steel. The sample shall be logged and classified in accordance with SOP ENV-05-02. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP ENV-04-04.

7.6 Test Pit Excavation and Sampling

Test pits, including trenches, consist of open shallow excavations used to determine the subsurface conditions for engineering and geological purposes. Test pits are typically conducted for subsurface characterization and to investigate underground structures that may contain impacts. Test pits shall be excavated manually or by machine (e.g. backhoe, bulldozer, or trackhoe), as required by the Site-Specific Work Plan or otherwise specified, and will be in accordance with OSHA regulations, 29 CFR 1926, 29 CFR 1910.120, and 29 CFR 1910.134. Test pit shall be logged and classified in accordance with SOP ENV-05-06.

Soil samples shall be collected from the backhoe/trackhoe bucket or directly from the wall or base of the test pit, depending on the depth of the pit. Disturbed samples shall be collected using a stainless steel scoop, shovel, or trowel. Undisturbed samples shall typically be collected using a hand auger and/or other coring tool. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP ENV-04-04.

7.7 Surface Soil Sampling

Surface soil samples are collected to determine the surface soil conditions. Surface soil samples are generally collected at depths of less than 1 to 3 feet below the ground surface or as defined in SSWPs, considering DQOs. The use of discrete or composite samples will be determined in the SSWPs.

Before sample collection, all surface materials (i.e., excess gravel, vegetation, etc.) shall be removed from the sample location. Soil samples shall be collected using a stainless steel scoop, trowel, hand auger, or other equipment as required by the Site-Specific Work Plan or otherwise specified. Samples for chemical analyses and/or geotechnical testing shall be collected using the laboratory-approved and analytical-method required sample containers. The sampling equipment shall then be decontaminated in accordance with SOP ENV-04-04. The sample appearance, depth, and location should be recorded in the field logbook and/or on appropriate field form using the standardized descriptions in SOP ENV-05-03, Attachment E.

8.0 ANALYTICAL SAMPLE PREPARATION

Sections of the sample representative of the entire sampling interval shall be selected for chemical analyses and/or geotechnical testing. Based on analytical requirement and contracted laboratory specifications, chemical analysis samples shall be placed in appropriate sample containers. Specific analytical sample preparation procedures are as follows.

- Using a decontaminated sampling instrument, remove the desired thickness and volume of from the sample retrieval device.
- Conduct a direct screening of the sample with a photoionization detector (PID).
- Visual observations of affected soil will use the descriptors from SOP ENV-05-02 Attachment E.
- Describe and classify the sample in accordance with SOP ENV-05-02, Field Logging of Soil and Rocks.
- **Volatile Organic Compounds (VOCs) –** Discrete soil samples for VOC analyses will be collected as soon after sample retrieval as possible. Unless otherwise specified, soil samples for VOC analyses shall be collected by either Powerstop Handle^{TM} or EnCore^{TM} sampler methods in conformance to USEPA

Method 5035 requirements. Attachment A presents procedures for Powerstop Handle™ and EnCore™ sample collection. Secure container lid, apply label containing sample identification information and place in cooler with ice.

- **Semivolatile Organic Compounds (SVOCs), Metals, Cyanide, PCBs, Pesticides, Herbicides, and Organic Carbon –** Soil samples for these analytes will be collected after collecting VOCs. Place soil in a container for homogenization. Samples will be homogenized using clean stainless steel mixing bowls, spoons, knifes, etc. Sample aliquots will be placed directly from the sample retrieval device into the stainless steel bowl. The soil will be thoroughly mixed in the bowl to homogenize the sample and then placed directly into appropriate sample containers. Secure container lid, apply label containing sample identification information and place in cooler with ice.
- **Physical Characteristics –** For geotechnical testing of cohesive samples, cut minimally disturbed sections of the specimen and place it in the appropriate sample container. Samples for geotechnical testing, including Shelby tubes shall be handled and packaged in accordance with standard practices for geotechnical investigations or as required by the Site-Specific Work Plan or otherwise specified. If contamination potentially exists, samples shall be identified as potentially containing hazardous or toxic chemicals.
- Samples shall be identified, labeled, documented and prepared for transport in accordance with SOP ENV-03-01, Sample Identification, Labeling, Documentation and Packaging for Transport.
- SOP ENV-03-2 Chain-of-Custody procedures shall be followed in preparing the samples for transport to the analytical laboratory.
- Sampling equipment and tools shall be decontaminated between each sample in accordance with SOP ENV-04-05.

Containerize any investigation-derived solid and liquid waste, including decontamination water, label and store for disposal at an appropriate disposal facility. Consult with Project Manager regarding disposal of waste.

Samples should be preserved and holding times should be observed according to analytical requirements and laboratory specifications, as required by the Site-Specific Work and/or FSPs, or as otherwise specified. If replicate or split samples are required, adjust the sections so that the additional samples are essentially identical.

9.0 DOCUMENTATION

Sample identification, labeling, and custody control shall be performed in accordance with requirements specified in SOP ENV-03-01 and ENV-03-02. Specific procedures for describing the samples and logging subsurface soil samples are presented in SOP ENV-05-03. Soil sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work Plan.

10.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 1999, D1586-99 Standard Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM International, 2000, D4220-95 (2000) Practices for Preserving and Transporting Soil Samples.

ASTM International, 2004, D5730-04 Guide for Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone, and Ground Water.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
ENCORE^{TM} AND POWERSTOP HANDLE^{TM} SAMPLING PROCEDURES

Author:	T. Gilles	Q2R & Approval By:	C. Barry	Q3R & Approval By:	M. Kelley

ENCORE^{TM} SOIL SAMPLING PROCEDURE

- Remove EnCore™ sampler and cap from its re-sealable pouch and attach T-handle to sampler body. (**Note**: when dealing with soft or sandy solid, it may be necessary to retract the plunger in the sampler before sample collection.)
- Using the T-handle for leverage, push the sampler into a freshly exposed surface of soil until the sampler is full.
- Brush any soil off the sampler head and securely attach the sampler cap by pushing with a twisting motion.
- Complete the sample label and attach to the sampler body; place labeled sampler in its re-sealable pouch and seal the pouch.
- Repeat the procedure for two additional samples collected from the same soil stratum or the same area. (**Note:** this step may be eliminated or the number of samples reduced if the suspected level of VOCs is known [i.e., low or high concentration sample]. Consult method 5035 or discuss procedure with an analytical laboratory for further details.)
- Use a stainless steel spoon or similar tool to collect an additional sample from the same soil stratum or the same area. Place collected material in a 2-ounce, wide-mouth jar with no preservatives. (**Note:** this additional soil volume is for dry weight and percent moisture determination. This step is not necessary if additional soil from the sample location is collected for other parameter analyses upon which dry weight and percent moisture will be determined.)
- Immediately place samples in a cooler with ice.

Ship EnCore™ samples (next day priority delivery) to the contract laboratory the day they are collected. Alternatively, arrange to have samples picked-up by the laboratory or delivered to the laboratory by field personnel within 24 hours of collection. These sample shipment or pickup timelines must be achieved to ensure the laboratory performs sample preservation or analysis within 48 hours of sample collection.

POWERSTOP HANDLE™ SAMPLING PROCEDURES

1. **Load Sampling Device**

   Insert EasyDraw Syringe™ into the appropriate slot (5 or 10-gram heavy, 5 or 10-gram medium, 5 or 10-gram light or 13 gram position) on the Powerstop Handle™ device and remove end cap from syringe.

   EPA Method 5035 Recommended 5-gram slot positions:

   - Use the heavy position for dense clay;
   - Use the light position for dry sandy soil; and
   - Use the medium position for all others.

2. **Collect Sample**

   Push EasyDraw Syringe™ into a freshly exposed surface of soil until the syringe is full. Continue pushing until the soil column inside the syringe has forced the plunger to the stopping pint. (**Note**: unlike other sample collection devices, there is no headspace air in the syringe to displace.) EasyDraw Syringe™ delivers approximately 5, 10, or 13 grams. Actual weight will be determined at the laboratory. No scale or balance required in the field.

3. **Eject Sample Into Vial**

   Remove the syringe from the Powerstop Handle™ device and insert the syringe into the open end of 40-ml vial, and eject sample into <u>pre-tared</u> vial by pushing on the syringe plunger. Avoid getting dirt on the threads of the 40-ml vial. Cap vial immediately and put on ice. Sample must be received by within 48 hours of sampling if samples are not chemically preserved in the field.

SOP SERIES SAS-07

SEDIMENT SAMPLING AND MEASUREMENT PROCEDURES

Author:	**C. Barry**	**Q2R & Approval By:**	**J. Gonzalez**	**Q3R & Approval By:**	**M. Kelley**

STANDARD OPERATING PROCEDURE
NO. SAS-07-03

SEDIMENT SAMPLING
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) presents guidelines for selecting sediment sampling locations and general procedures for the collection of sediment samples. This SOP addresses continental sediments only. Estuarine and oceanic sediment sampling is beyond the scope of this document and will not be discussed. This SOP addresses sample collection for characterization of chemical or physical parameters. Requirements for collection of samples for biological characterization are addressed in a separate SOP.

2.0 EQUIPMENT AND MATERIALS

Sampling equipment and materials vary be collection method. However, some standard equipment and materials are required regardless of collection method:

- Ruler or tape measure in 0.01 –foot increments;
- Sample containers and labels;
- Sample cutting/extracting equipment (scoops, spatulas, trowels, shovels, etc.);
- Field logbook and/or the appropriate field form(s);
- Depth measurement devices;
- Decontamination materials;
- Chain of custody forms;
- Custody seals;
- Coolers and ice packs;
- Personal protective equipment;
- Camera; and
- Global positioning system (GPS) (optional).

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 PERMITTING

Sampling performed within navigable waters and critical habitats may fall under the jurisdiction of one or more federal, state, or local agencies, including by not limited to the United States Army Corp of Engineers (USACOE), US Department of Fish and Wildlife, and state Department of Natural Resources. Prior to the commencement of sampling activities, appropriate permit(s), if applicable, shall be obtained.

5.0 SAMPLE SITE SELECTION

The sediment sampling site will be selected based on a number of factors including among others the presence of environmental impacts on adjacent land, presence of water discharge or outfall area, type of water body (e.g. lake, river, pond, etc.), sediment type, and depth to sediment. In water that is generally navigable, the only requirement for site selection may be ability to access the investigational site by boat. Sediment investigations in rivers, creeks or canals, will usually require additional information for sample site selection including such factors as stream flow velocity; depth, cross section and plan view of stream, and man-made and natural structures that affect stream flow, among others. In many cases, the USACOE and state geological surveys have extensive records for US waters and should be consulted prior to sediment sampling site selection. An experienced geologist or hydrologist should also be consulted prior to site selection.

A pre-sampling site visit is necessary to determine access points and best locations for sampling. Current aerial or satellite photographs of the site may be viewed prior to the initial site visit to obtain a general overview of possible access and sampling locations. Sampling sites may be selected during the site reconnaissance. Sampling locations can be indicated by reference to onshore features, such as buildings, fence lines, trees, etc. If natural features, such as trees are used, they will be marked by paint or colored flags for easy identification. A sketch map will be drawn in the field logbook or on a field form showing reference points and any measurements to be used to locate sampling points. If offshore sites are selected, a GPS can be used to find latitude and longitude coordinates for sampling points. These coordinates will be recorded on a site sampling map or field form, and in the field logbook.

6.0 SEDIMENT SAMPLING EQUIPMENT

Sediment sampling devices will be selected based on depth to sediment, type of sediment, type and size of sample required. Shallow sediment samples can be collected by trowel, scoop or shovel, which is decontaminated before use and between use at each specific sampling location. Manual augering equipment (tube or bucket auger); manual coring devices with Teflon or acetate liners; or barge-mounted machine augering (e.g., hollow-stem) equipment can be used to collect samples. Dredging equipment can be used for larger samples including Peterson, Eckman, and Ponar dredges. Selected sediment sampling methods have been outlined below.

Additionally, a sediment sampling equipment selection table (Attachment A), which was adapted from Ohio EPA, Sediment Sampling Guide (Ohio EPA 2001) and USEPA SOP #2016 – Sediment Sampling provides (USEPA 1994), provides alternative information for selection and use of sediment sampling equipment. The Site-Specific Work Plan will specify the sampling equipment and method(s) to be used. Sampling equipment should be selected to minimize disturbance of potentially impacted sediments.

6.1 Shallow Sediment Sampling Methods

If the water is wadeable, a sediment sample may be collected by scooping the sediment using a stainless steel spoon or scoop, reducing the potential for cross-contamination. This can be accomplished by wading into the stream, and while facing upstream (into the current), scooping the sample along the stream bottom in the upstream direction. If the stream is too deep to wade but less than eight feet deep, a stainless steel scoop attached to a piece of conduit can be used either from the banks if the stream is narrow or from a boat.

If the stream has a significant flow and is too deep to wade, a BMH-60 sampler may be used. It is not particularly efficient in mud or other soft substrates because its weight will cause penetration to deeper sediments, which are not desired when sampling for priority pollutants. It is also difficult to release secured samples in an undisturbed fashion that would readily permit sub-sampling. The BMH-60 may be used for priority pollutant sampling provided that caution is exercised by only taking sub-samples that have not been in contact with the metal walls of the sampler.

6.2 Core Sampling Methods

Core Sampling Methods are used to sample vertical columns of sediment. They are particularly useful when a historical approach to sediment deposition is desired for they preserve the sequential layering of the deposit. Many types of coring devices have been developed depending on the depth of water from which the sample is to be obtained, the nature of the bottom material, and the length of core to be collected. They vary from hand push tubes to weight or gravity driven devices.

Coring devices are particularly useful in pollutant monitoring because the "shock wave" created by descent is minimal, thus the fines of the sediment-water interface are only minimally disturbed; the sample is withdrawn intact permitting the removal of only those layers of interest; core liners manufactured of glass or Teflon® can be purchased, thus reducing possible sample contamination; and the samples are easily delivered to the lab for analysis in the tube in which they were collected. The disadvantage of coring devices is that a relatively small surface area and sample size is obtained often necessitating repetitive sampling in order to obtain the required amount for analysis. Because it is felt that this disadvantage is offset by the advantages, coring devices are recommended in sampling sediments for trace organic compounds or metals analyses.

Hand / Push Coring Devices may be used in shallow, wade-able waters. This method involves the direct use of a core liner or tube manufactured of Teflon® or glass is recommended for the collection of sediment samples. Their use can also be extended to deep waters when SCUBA equipment is available. Teflon® is preferred to avoid glass breakage and possible sample loss. Stainless steel push tubes are also acceptable and provide a better cutting edge and higher strength than Teflon®. The use of the glass or Teflon® tube by itself eliminates any possible metal contamination from core barrels, cutting heads, and retainers. The tube should be approximately 12 inches if only recently deposited sediments (8 inches or less) are to be sampled. Longer tubes should be used when the depth of the substrate exceeds eight inches. Soft or semi-consolidated sediments such as mud and clays have a greater adherence to the inside of the tube and thus can be sampled with larger diameter tubes. Because coarse or unconsolidated sediments such as sands and gravel tend to fall out of the tube, a small diameter is required for them. A tube about two inches in diameter is usually the best size. The wall thickness of the tube should be about 1/3 inch for either Teflon® or glass. The inside wall may be filed down at the bottom of the tube to facilitate entry of the liner into the substrate.

Caution should be exercised not to disturb the area to be sampled when the sample is obtained by wading in shallow water. The core tube is pushed into the substrate until only four inches or less of the tube is above the sediment-water interface. When sampling hard or coarse substrates, a gentle rotation of the tube while it is pushed will facilitate greater penetration and cut down on core compaction. The tube is then capped with a Teflon® plug or a sheet of Teflon® held in place by a rubber stopper or cork. After capping, the tube is slowly extracted, the negative pressure and adherence of the sediment keeping the sample in the tube. Before pulling the bottom part of the core above the water surface, it too is capped. With a few modifications, this method can also be applied to sample collection from the edge of a boat or barge.

Vibro-core sampling is described as an electrical powered sediment sampling system featuring a vibrator head that drives a core tube liner into the sediment. Liners, often containing cellulose acetate butyrate (CAB), can be up to 20 feet (6 meters) long and 4 inch inside diameter (ID); lengths are selected based on sediment measured. The sampling vessel should be triple anchored, moored to a secure fixture, or spudded prior to collecting cores. The following procedure is a suggested method to collect sediment core samples:

1. Measure the water depth and soft sediment thickness.
2. Insert core catcher into CAB tube.
3. Position core catcher, drill holes, and rivet into place with aluminum rivets.
4. Lift the vibrating head with the winch to a vertical position so that it is suspended just off the bow of the sampling vessel.
5. Insert the core tube into the vibrating head, making sure that the tube slides in all the way.

6. Tighten the collar to the vibro-core (two bolts on each side).
7. Lower the entire assembly until the core nose is just above the sediment surface. Care should be taken to ensure that the cutter head or end of the core tube does not come into contact with the vessel during deployment. Verify that the generator is on. Turn on the vibrating head.
8. Slowly lower the vibro-core by running out 6-10 inches of cable at a time. Monitor core tube penetration by feeling for slack in the cable. Note appropriate rate of penetration in field log (Appendix B).
9. When the vibro-core ceases to penetrate the sediment (stops lowering or is "refused"), or the vibrating head is near the sediment surface, reverse the winch and pull the unit from the sediment. Do not allow the vibrating head to become imbedded into the sediment.
10. Turn off the power to the vibrating head when the core breaks free of the sediment.
11. During retrieval, the coring device and core tube need to be maintained in a vertical position to minimize disturbance of the collected sediments. Lift the assembly so that the sediment/water interface is visible. Wash the excess sediment from the outside of the tube. Once out of the water, the cutter head should be inspected and a physical description of the material at the mouth of the core entered into the core log. Drill holes through tube at the sediment/water interface and decant water from tube.
12. Tie line around tube in a single or double clove hitch.
13. Disengage the tube and lay the sediment core on the deck. Saw off excess core tube at the sediment surface, and cap the top of the tube with a red cap plug. Both ends should then be secured tightly with duct tape to prevent leakage. The amount of sediment in the tube should be measured and recorded in the sample log, along with the overall condition of the core. The core tube then should be marked to denote: Location, Recovery Length, Top of Core, Date, and Time.
14. Handle and sub-sample core as desired, on board, or at a shore based location.

Ogeechee / Open Barrel Punch Corer. The core unit will be deployed from the sampling vessel by hand to collect an undisturbed sediment sample to a depth of approximately 4 feet below the sediment/surface water interface. The open barrel punch-core will be manned by a minimum of two crewmembers: one staff member or contractor will handle the deployment and retrieval of the core while the vessel operator controls the boat and records the sampling location.

1. Make field notes and logbook entries as necessary throughout the sampling process to ensure thorough and accurate record keeping.
2. Maneuver the boat to the sampling location as identified in the project SSWP or based on field encountered conditions/data.
3. Measure and record the depth to sediment and sediment thickness using poling methods. This information will be used for comparison with any hydrographic survey results.
4. Place the liner (thin-walled tube) inside the core-barrel sampler followed by the core catcher. Open the check valve located atop the core unit. Attach lengths of rod to the core unit to enable the operator to push the core down to the appropriate depth. The rods also allow for the use of weights to help drive the core if needed.
5. Guide the core overboard.
6. Lower the core to the sediment surface at approximately 1.0 feet per second (ft/sec) so as to minimize sediment surface disturbances.
7. Record the location of the boat when sampler reaches bottom.
8. Push or use the weights to drive the sampler to the depth specified in the SSWP or based on field encountered conditions/data.
9. Close the check valve on the barrel core sampler and begin retrieving the sampler, raising it at approximately 1.0 ft/sec.
10. Guide the core on board the vessel and place it on the worktable on the deck; use care to avoid jostling that might disturb the integrity of the sample. Remove the core liner from the barrel.
11. Examine the sample for the following sediment acceptance criteria:
    - The sampler is not overfilled so that the sediment is present in the retrieval rods;
    - No leakage has occurred, as indicated by the presence of sediment at the end of the core tube;
    - No sample disturbance has occurred, as indicated by limited turbidity in the overlying water;
    - If sample acceptance criteria are not achieved, the sample will be rejected and the location re-sampled. If unable to obtain a sample that meets the appropriate acceptance criteria within 50 feet of the proposed location, the sample will be relocated as determined by the Project Manager or Task Manager, as appropriate.
12. Decant or siphon off free water from the surface of the sediment. Care should be taken to not disturb the integrity of the sediment surface. Extrude the sediment from the core liner.

13. Visually classify sediment, record the descriptions on the sediment sampling form, and photograph sample.
14. Repeat the sampling process (if necessary) until sufficient volume is obtained to satisfy the sampling requirements for each location. Collect successive core samples within a radius of 10 feet of the initial sampling location.
15. Handle and sub-sample core as desired, on board, or at a shore based location.

6.3 Dredge Sampling Methods

The Peterson dredge can be used when the bottom is rocky, in very deep water, or when the stream velocity is high. The dredge should be lowered very slowly as it approaches bottom, because it can displace and miss lighter materials if allowed to drop freely.

The Eckman dredge has only limited usefulness. It performs well where bottom material is unusually soft, as when covered with organic sludge or light mud. It is unsuitable, however, for sandy, rocky, and hard bottoms and is too light for use in streams with high velocities. It should not be used from a bridge more than a few feet above the water, because the spring mechanism which activates the sampler can be damaged by the messenger if dropped from too great a height.

The Ponar dredge is a modification of the Peterson dredge and is similar in size and weight. It has been modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends thus reducing the "shock wave." The Ponar dredge is easily operated by one person in the same fashion as the Peterson dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates.

1. Make field notes and logbook entries as necessary throughout the sampling process to ensure thorough and accurate record keeping.
2. Maneuver the boat to the sampling location as identified in the SSWP or based on field encountered conditions/data.
3. Measure and record the depth to sediment and sediment thickness using the poling methods. This information will be used for comparison with any hydrographic survey results.
4. Open the sampler and slide the locking pin into place.

5. Guide the sampler overboard.
6. Lower the sampler to the sediment surface at approximately 1.0 feet per second (ft/sec).
7. Record the location of the boat when sampler reaches bottom.
8. Begin retrieving the sampler and raise it at approximately 1.0 ft/sec.
9. Guide the sampler on board the vessel and place it on the worktable on the deck; use care to avoid jostling that might disturb the integrity of the sample.
10. Examine the sample for the following sediment acceptance criteria:
    - Sampler jaw is closed and the sample does not contain foreign objects
    - Desired penetration depth has been achieved
    - The sampler is not overfilled so that the sediment surface presses against the top of the sampler
    - No leakage has occurred, as indicated by overlying water on the sediment surface
    - No sample disturbance has occurred, as indicated by limited turbidity in the overlying water
    - No winnowing has occurred, as indicated by a relatively flat undisturbed surface
    - If sample acceptance criteria are not achieved, the sample will be rejected and the location re-sampled. If unable to obtain a sample that meets the appropriate acceptance criteria within 50 feet of the proposed location, the sample will be relocated as determined by the Project Manager or Task Manager, as appropriate.
11. Decant or siphon off free water from the surface of the sediment. Care should be taken to not disturb the integrity of the sediment surface.
12. Visually classify sediment, record the descriptions on a sediment sampling form, and photograph sample.
13. Collect the sediment from the sampler using a stainless steel implement and care not to include any material that has been in contact with any interior sampler surface. Place this sediment into an appropriate-sized stainless steel homogenization bowl.
14. Thoroughly rinse the interior of the sampler until all loose sediment has been washed off.
15. Repeat the sampling process (if necessary) until sufficient volume is obtained to satisfy the sampling requirements for each location. Collect successive grab samples within a radius of 10 feet of the initial sampling location.
16. Homogenize the bulk sediment until it has uniform color and texture.
17. Place samples into containers in accordance with SSWP.

18. Clean the exterior of all sample containers and store them in a cooler with ice.

7.0 SAMPLE COLLECTION PROCEDURES

- Prior to mobilization to the field, consult with the contracted analytical laboratory to ascertain if they require any sediment-specific sample collection procedures to be followed to ensure that samples are acceptable for the analyses to be conducted and provided in adequate volume for analyses.
- Sampling locations will be located horizontally using a Global Positioning System (GPS) receiver in the field. Either Real Time Kinematic (RTK), or Differential GPS (DGPS) may be used to achieve sub-foot accuracy.
- Sampling locations will be estimated vertically using a graduated pole in combination with site staff gauge. If a staff gauge has not been established at the site, a staff gauge shall be established and surveyed accurate to ±0.01 feet. Prior to sample collection, a graduated pole will be used to measure the top of sediment relative to surface water. The estimated elevation each sediment sample will be calculated in the office using the surface water elevations measured from the site staff gauge. Measurements shall be collected from the site staff gauge multiple times throughout each day of sampling to account for fluctuating water levels.
- Using a decontaminated sampling instrument, remove the desired thickness and volume of sediment from the sampling location.
- When coring sediments, the penetration depth, recovery depth, and percent recovery shall be recorded on a sediment sampling field form (Appendix B)
- If sediment is not saturated, conduct a direct screening of the sample with a photoionization detector (PID).
- Describe and classify the sample in accordance with SOP ENV-07-02, Description and Classification of Sediments and record observations on a sediment sampling field form (Appendix B).
- **Volatile Organic Compounds (VOCs) –** Discrete sediment samples for VOC analyses will be collected as soon after sample retrieval as possible. Any surface water should be decanted from the sediment before collecting the samples. Pre-preserved vials or jars with Teflon-lined lids will be used if moisture content of soil is too high to allow collection of 5-gram samples for vials. Attachment B provides a detailed sampling procedure for pre-preserved vials. If jars are used, they will be filled to provide zero-headspace samples. Secure container lid, apply label containing sample identification information and place in cooler with ice.

- **Semivolatile Organic Compounds (SVOCs), Metals, Cyanide, PCBs, Pesticides, Herbicides, and Organic Carbon –** Sediment samples for these analytes will be collected after collecting VOCs. Any surface water should be decanted from the sediment before placing it in a container for homogenization. Samples will be homogenized using clean stainless steel mixing bowls, spoons, knifes, etc. Sample aliquots will be placed directly from the sample retrieval device into the stainless steel bowl. The soil will be thoroughly mixed in the bowl to homogenize the sample and then placed directly into appropriate sample containers. Secure container lid, apply label containing sample identification information and place in cooler with ice.
- **Physical Characteristics –** Sediment samples collected for physical characterization should be carefully placed into a large glass jar directly from the sampler to mitigate sample disturbance. Secure container lid, apply label containing sample identification information and place in transportation container.
- Samples shall be identified, labeled, logged, stored and prepared for shipment in accordance with SOP ENV-03-01, Sample Labeling, Logging, Storage and Shipment.
- SOP ENV-03-02 Chain-of-Custody procedures shall be followed in preparing the samples for transport to the analytical laboratory.
- Sampling equipment and tools shall be decontaminated between each sample in accordance with SOP ENV-04-04.
- Containerize any investigation-derived solid and liquid waste, including decontamination water, label and store for disposal at an appropriate disposal facility. Consult with Project Manager regarding disposal of waste.

8.0 DOCUMENTATION

Sampling activities shall be documented as outline in SOP ENV-01-01 and as specified the Site-Specific Work Plan. Visual observations are particularly important and may prove invaluable in interpreting sediment quality study results. Visual observations of affected sediment will use the descriptors from SOP ENV-05-02, Attachment E. These visual observations, including weather and water body conditions during the sampling event, shall also be recorded in the field logbook and/or on the appropriate field form (Appendix B).

9.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, 2003, D3975-93(2003) Standard Practice for Development and Use (Preparation) of Samples for Collaborative Testing of Methods for Analysis of Sediments.

ASTM International, 2005, D3976-92(2005) Standard Practice for Preparation of Sediment Samples for Chemical Analysis.

ASTM International, 2003, D4823-95(2003)e01 Guide for Core Sampling Submerged, Unconsolidated Sediments.

Ohio Environmental Protection Agency, Division of Surface Water, 2001, Sediment and Sampling Guide and Methodologies, 2nd Ed., November.

USEPA Region V, 1984, Methods Manual for Bottom Sediment Sample Collection, EPA-905-4-004, May.

USEPA, 1994, SOP #2016 – Sediment Sampling, November 17.

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

ATTACHMENT A
SEDIMENT SAMPLING EQUIPMENT SELECTION TABLE

SEDIMENT SAMPLING EQUIPMENT SELECTION TABLE[1,2]

Sample Type	Model	Current	Substrate	Remarks
GRAB	Spoon Scoop	Zero To Slight	All	• Use only in relatively calm and shallow water • Relatively little sample disturbance • Simple and inexpensive • Fines may washout when retrieved through water column
CORE	Tube Auger	Zero To Slight	Clay and Silt	• Use only in relatively calm and shallow water • Extension handles can be used for deeper waters. • Relatively little sample disturbance • Simple and inexpensive • Fines may washout when retrieved through water column
CORE	Bucket Auger	Zero To Slight	Clay to Fine Gravel	• Use only in relatively calm and shallow water • Extension handles can be used for deeper waters. • Relatively little sample disturbance • Simple and inexpensive • Fines may washout when retrieved through water column
GRAB	Eckman	Zero To Very Slight	Clay and Silt	• Use in relatively calm water • Pebbles and branches may interfere with jaw closure • Excellent jaw shape and cut • Relatively little sample disturbance • Poor stability – Light weight allows for tendency to “swim” in a current, which sometimes causes miss triggers • 0.02 square meter sample area • Weight with sample is 10 kilograms

[1] Ohio Environmental Protection Agency, Division of Surface Water, 2001, Sediment and Sampling Guide and Methodologies, 2nd Ed., November.
[2] USEPA, 1994, SOP #2016 – Sediment Sampling, November 17.

SEDIMENT SAMPLING EQUIPMENT SELECTION TABLE[1,2] (Continued)

Sample Type	Model	Current	Substrate	Remarks
GRAB	Petite Ponar Peterson	Zero To Very Slight	Clay to Fine Gravel	• Needs relatively calm/sheltered waters • Good stability • Poor jaw shape and cut • Sample disturbance • Less washout if extra weights are used • More cumbersome than an Eckman – Requires a winch • 0.1 – 0.2 square meter sample area • Weight with sample is 30 – 50 kilograms
CORE	Manual	Zero To Strong	Clay to Sand (Inserts needed for sandy samples)	• Recommended for use in shallow water • Deployed by hand or driver (hammer) • Extension handles can be used for deeper waters.
CORE	Coring Tubes	Zero To Moderate	Clay to Sand (Inserts needed for sandy samples)	• Quick and easy • Relatively undisturbed sample • Small sample volume • Samples sometimes compressed
CORE	Gravity	Zero To Moderate	Clay and Silt	• Recommended for rivers • Depths up to 10 meters
CORE	Split Spoon	Zero To Moderate	Clay to Sand (Inserts needed for sandy samples)	• Recommended for use in shallow water • Deployed by hand or driver (hammer) • Vertical profile remains intact and is visible • Point design can reduce sample compaction • Stones can interfere with collection • Equipment is heavy

[1] Ohio Environmental Protection Agency, Division of Surface Water, 2001, Sediment and Sampling Guide and Methodologies, 2nd Ed., November.
[2] USEPA, 1994, SOP #2016 – Sediment Sampling, November 17.

ATTACHMENT B
ENCORE AND POWERSTOP SAMPLING PROCEDURES

ENCORE™ SOIL SAMPLING PROCEDURE

- Remove EnCore™ sampler and cap from its re-sealable pouch and attach T-handle to sampler body. (**Note**: when dealing with soft or sandy solid, it may be necessary to retract the plunger in the sampler before sample collection.)

- Using the T-handle for leverage, push the sampler into a freshly exposed surface of sediment until the sampler is full.

- Brush any soil off the sampler head and securely attach the sampler cap by pushing with a twisting motion.

- Complete the sample label and attach to the sampler body; place labeled sampler in its re-sealable pouch and seal the pouch.

- Repeat the procedure for two additional samples collected from the same soil stratum or the same area. (**Note:** this step may be eliminated or the number of samples reduced if the suspected level of VOCs is known [i.e., low or high concentration sample]. Consult Method 5035 or discuss procedure with an analytical laboratory for further details.)

- Use a stainless steel spoon or similar tool to collect an additional sample from the same sediment stratum or the same area. Place collected material in a 2-ounce, wide-mouth jar with no preservatives. (**Note:** this additional soil volume is for dry weight and percent moisture determination. This step is not necessary if additional soil from the sample location is collected for other parameter analyses upon which dry weight and percent moisture will be determined.)

- Immediately place samples in a cooler with ice.

Ship EnCore™ samples (next day priority delivery) to the contract laboratory the day they are collected. Alternatively, arrange to have samples picked-up by the laboratory or delivered to the laboratory by field personnel within 24 hours of collection. These sample shipment or pickup timelines must be achieved to ensure the laboratory performs sample preservation or analysis within 48 hours of sample collection.

POWERSTOP HANDLE SAMPLING PROCEDURE

1. Load Sampling Device

Insert EasyDraw Syringe™ into the appropriate slot (5 or 10-gram heavy, 5 or 10-gram medium, 5 or 10-gram light or 13 gram position) on the Powerstop Handle™ device and remove end cap from syringe.

EPA Method 5035 Recommended 5-gram slot positions:

- Use the heavy position for dense clay;
- Use the light position for dry sandy soil; and
- Use the medium position for all others.

2. Collect Sample

Push EasyDraw Syringe™ into a freshly exposed surface of soil until the syringe is full. Continue pushing until the soil column inside the syringe has forced the plunger to the stopping pint. (**Note**: unlike other sample collection devices, there is no headspace air in the syringe to displace.) EasyDraw Syringe™ delivers approximately 5, 10, or 13 grams. Actual weight will be determined at the laboratory. No scale or balance required in the field.

3. Eject Sample Into Vial

Remove the syringe from the Powerstop Handle™ device and insert the syringe into the open end of 40-ml vial, and eject sample into pre-tared vial by pushing on the syringe plunger. Avoid getting dirt on the threads of the 40-ml vial. Cap vial immediately and put on ice. Sample must be received by within 48 hours of sampling if samples are not chemically preserved in the field.

SOP SERIES SAS-08

GROUNDWATER SAMPLING AND MEASUREMENT PROCEDURES

Author:	J. Sapp / T. Gilles	Q2R & Approval By:	A. Bazan	Q3R & Approval By:	M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-08-01

GROUNDWATER AND NON-AQUEOUS PHASE LIQUID MEASUREMENT
Revision 1

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to describe method(s) to measure groundwater, Light Non-Aqueous Phase Liquids (LNAPL) and Dense Non-Aqueous Phase Liquids (DNAPL) elevations and thicknesses in groundwater monitoring wells, observation wells, and recovery wells as required in the Site-Specific Work Plan or as otherwise specified.

2.0 EQUIPMENT AND MATERIALS

- Notebook, field logbook, and/or the field activity form;
- Steel add-on tape or electronic water level indicator;
- Electronic water level indicator;
- Electronic oil/water interface probe;
- Pressure transducer (as appropriate for the conditions);
- Gasket adapted to the diameter of the transducer cable;
- Data logger;
- Decontamination equipment and supplies (in accordance with the guidelines in SOP ENV-04-05).
- Personal protective equipment; and
- Chalk

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL REQUIREMENTS

Water level, LNAPL, and DNAPL (if present) measurements should be obtained at wells designated in the Site-Specific Work Plan. Water level, LNAPL, and DNAPL levels should be measured in referenced to a common elevation or datum, preferably to a USGS benchmark located at the site. Water level, LNAPL, and DNAPL depths should be measured from a reference point marked on the top of the casing, which, in turn, is referenced to a permanent benchmark.

Water and product level measurement devices shall be decontaminated as per SOP ENV-04-05 or as specified in the Site-Specific Work Plan before and after measuring at each location.

Care shall be exercised to avoid direct skin contact while measuring water level and product depth. All equipment should be decontaminated before and after each measurement as per SOP ENV-04-05. Water and product level measurements should be recorded in the field logbook and/or the field activity form.

5.0 MEASUREMENT METHODS AND PROCEDURES

5.1 Discrete Groundwater Level Measurement

Discrete water level measurements should be made by determining the depth to the water surface from the top of the well casing at the fixed reference point. The fixed reference point is established by permanently marking a point on the outer edge (lip) of the well casing. Caution should be exercised so that filings do not fall into the well.

The depth to water can be determined using a steel add-on tape or electronic water level indicator. The steel add-on tape consists of a measuring tape that has 1-foot increments and a 1-foot section at the end of the tape with 0.01-foot increments. The end of the tape is coated with chalk and lowered into the well. The water depth is read from the saturated mark on the chalked tape and added to the depth interval measured at the top of the well casing

Electronic water level indicators are conducting probes that activate an alarm and a light when they intersect the water. The sounder wire is marked in 0.01-foot intervals to indicate depth. All sounders are equipped with weights to maintain line tension for accurate readings. The typical operating procedures for an electronic water level indicator are as follows:

- Lower the sounder wire until it just makes contact with the water in the well and the indicator light goes on or the pulsating alarm is sounded. Record the position of the wire relative to the reference point at the top of the well casing. Record the actual water level reading to the nearest 0.01-foot. Repeat to confirm depth.
- Withdraw the sounder from the well.
- Record the water depth in the field logbook and/or the field activity form.
- Decontaminate the sounder wire and electrode in accordance with SOP ENV-04-05.

Discrete water levels are typically required from a series of wells when data for preparing groundwater contour maps are needed. However, discrete water levels may also be required when monitoring the changes in water level during aquifer testing if aquifer response is sufficiently slow. Continuous water level measurements are discussed in Section 5.4 of this SOP.

5.2 Discrete LNAPL Level Measurement

Discrete LNAPL or product level measurements should be made by determining the depth to the product and water surface from the top of the well casing at the fixed reference point. The fixed reference point is established by permanently marking a point on the outer edge (lip) of the well casing. Caution should be exercised so that filings do not fall into the well.

The depth of the product and water level may be obtained using an electronic oil/water interface probe. An oil/water interface probe has a multi-conducting probe that activates different signals, typically pulsating beeps and continuous alarms, when they intersect the product and water, respectively. The sounder wire is marked in 0.01-foot increments to indicate depth. The interface probe is equipped with a weight to maintain line tension and obtain accurate readings. The typical operating procedures for an electronic oil/water interface probe are as follows:

- Check the interface probe battery by pressing the test button to ensure the device is operating properly before and after taking the level measurement. Daily battery checks should also be made and documented in the logbook.
- Lower the interface probe until it makes contact with the product in the well and the product indicator light goes on or the continuous alarm is sounded. Record the position of the wire relative to the reference point to the nearest 0.01-foot. Repeat to confirm the depth of the product.
- Continue to lower the interface probe, through the product layer, until it makes contact with the water level in the well and the water indicator light goes on or the pulsating alarm is sounded. Record the position of the wire to the reference point to the nearest 0.01-foot. Repeat to confirm the depth of the water.
- Withdraw the probe from the well.
- Record the product and water depth in the field logbook and/or the field activity form.
- Decontaminate the sounder wire and probe in accordance with the guidelines in SOP ENV-04-05.

Alternatively, the depth to the top of LNAPL may be approximated to the tenth of an inch with a weighted standard measuring tape. The thickness of LNAPL will be approximated using a bottom filling, clear, disposable bailer. The bailer may be slowly lowered into the water column, just below the approximate surface and allowed to fill. The bailer will be gently removed from the well to minimize disturbance. Measurements of the observed thickness of LNAPL will be measured to the nearest 0.1-foot using a standard measuring tape and recorded in the field logbook and/or the field activity form.

5.3 Discrete DNAPL Level Measurement

Discrete DNAPL or product level measurements should be made by determining the depth to the product and water surface from the top of the well casing at the fixed reference point. The fixed reference point is established by permanently marking a point on the outer edge (lip) of the well casing. Caution should be exercised so that filings do not fall into the well.

The depth of the water and product level may be obtained using an electronic oil/water interface probe. An oil/water interface probe has a multi-conducting probe that activates different signals, typically continuous alarms and pulsating beeps, when they intersect the water and product, respectively. The sounder wire is marked in 0.01-foot increments to indicate depth. The interface probe is equipped with a weight to maintain line tension and obtain accurate readings. The typical operating procedures for an electronic oil/water interface probe are as follows:

- Check the interface probe battery by pressing the test button to ensure the device is operating properly before and after taking the level measurement. Daily battery checks should also be made and documented in the logbook.
- Lower the interface probe until it makes contact with the water in the well and the water indicator light goes on or the beeping alarm is sounded. Record the position of the wire relative to the reference point to the nearest 0.01-foot. Repeat to confirm the depth of the water.
- Continue to lower the interface probe, through the water, until it makes contact with the product level in the well and the product indicator light goes on or the continuous alarm is sounded. Record the position of the wire to the reference point to the nearest 0.01-foot. Repeat to confirm the depth to the product.
- Withdraw the probe from the well.
- Record the water and product depth in the field logbook and/or the field activity form.
- Decontaminate the sounder wire and probe in accordance with the guidelines in SOP ENV-04-05.

Alternatively, the measurements of DNAPL may be approximated using a bottom filling, clear, disposable bailer. The bailer may be slowly lowered into the water column, to the bottom of the well and allowed to fill. The bailer will be gently removed from the well to minimize disturbance. Measurements of the observed thickness of DNAPL will be measured to the nearest 0.1-foot using a standard measuring tape and recorded in the field logbook and/or the field activity form.

5.4 Continuous Water Level Measurement

Continuous water level measurements are made by determining the height of the water column above a pressure transducer and electronically recording fluctuations in this height with a data logger. The continuous recording of height of water above the transducer is used for aquifer testing where rapid changes in water level are anticipated. The typical operating procedures for a continuous water level system are as follows:

- Enter the program into a data logger that has fully charged batteries. Alkaline batteries are preferred. During use, the battery voltage should not drop below the minimum voltage specified by the manufacturer; damage to the data logger and loss of recorded data could result.

- Select a pressure transducer for use in a given well that is compatible with both water quality and anticipated pressure sensitivity range (i.e., 5 psi, 30 psi, etc.). The pressure range selected is dictated by the anticipated range in the water column above the transducer and by the desired precision in measurement.
- Connect the transducers to the data logger in the field following manufacturer's instructions. Typically, four to eight input channels are available on the system. Other factors affecting the sampling configuration include cable length; distance between monitored wells; terrain; local human activities (traffic, plant operations); and the ability to secure the system from weather and vandals.
- Attach the transducer cable to the data logger and calibrate in air according to manufacturer's instructions. If multiple data loggers are used, internal clock synchronization should also be performed.
- Measure water level and depth to the bottom of the well before lowering the transducer into the well. Water levels are measured with an electrical water level indicator; total depth of the well is measured with a device compatible with well depth.
- Secure a sanitary fitting (commonly a gasket adapted to the cable diameter) at the surface of the well. Lower transducer into the well through the sanitary fitting to a depth between the water level and the bottom of the well. The transducer must be kept submerged during the period of measurement. Take care to keep the piezometric crystal at the tip of the transducer out of any fine sediment that has accumulated in the bottom of the well. On some transducers, the crystal is protected from sediment intrusion. Measure water level again; record the time indicated on the data logger digital display and water level. From these readings (and other periodic manual water level measurements), the water levels can be converted to elevations.
- Transfer data stored in the data logger periodically to a portable computer. The frequency of data transfer depends on available memory and conditions encountered in the field. Data may be transferred as frequently as daily. If the data logger has a wrap-around memory, the information should be transferred so that records are not recorded over.

6.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-08-02

LOW-FLOW GROUNDWATER SAMPLING
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures and guidelines for conducting low-flow groundwater sampling. This SOP provides a method that minimizes the impact of the purging process on groundwater chemistry and volume of water for disposal.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Well construction information;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (electronic water level indicator, interface probe, or weighted steel tape);
- Adjustable rate peristaltic pump or an adjustable rate low-flow submersible or positive displacement bladder pump (Note: The Site-Specific Work and/or Field Sampling Plan (FSP) shall specify the type of pump required);
- 1/4 to 3/8-inch Teflon®, polyvinyl chloride (PVC), or polypropylene tubing;
- Flow measurement supplies (e.g. graduated cylinder and stop watch);
- Power source, if applicable;
- Compressed inert gas source (for use with bladder pump), if applicable;
- Flow-through cell;
- Groundwater quality/indicator parameter monitoring instruments (flow-through cell capable);
- Instrument operation manual(s);
- Instrument calibration standard(s);
- Container(s) for purge water storage (e.g. 5-gallon buckets, polyethylene storage tank, etc.);
- Sample containers and labels, as appropriate for the analytical method(s) selected;
- Field filtration equipment, if applicable;

- Chain of custody forms and seals;
- Cooler(s) with double-bagged ice;
- Polyethylene sheeting, as appropriate;
- Decontamination materials;
- Personal protection equipment; and
- Field logbook and/or appropriate field form.

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 APPLICATION OF SAMPLING METHOD

Low-flow is one of several acceptable sampling procedures and may be performed using bladder or peristaltic pumps. Peristaltic pumps may be used when the well depth is less than or equal to fifteen feet, in zones of high contamination, or as approved in a SSWP. The sampling method may be modified to demonstrate attainment of cleanup goals in the future. Low-flow sampling shall not be used when one or more of the following conditions are present:

- Well will not accept or allow placement of the sampling device;
- Non-aqueous phase liquids (NAPLs). Reference SOP SAS-08-07 when sampling wells with NAPL;
- Formation screened will not allow drawdown to stabilize; and
- Water column is less than 2 feet in height.

5.0 EXECUTION

To the extent practical, sampling shall begin at the monitoring well with the least contamination and proceed systematically to the monitoring wells with the most contamination using the procedure outlined in the following subsections unless otherwise required by the Site-Specific Work and/or FSPs.

5.1 Preparation

The sampler shall create a work area around the monitoring well to minimize the potential for cross-contamination. Work area preparations may include the placement of polyethylene sheeting prevent sampling equipment from coming in contact with the ground surface. The sampler shall barricade and/or flag the work area, if required by the Site-Specific HASP. The sampler shall also arrange the sampling equipment and supplies to facilitate efficient execution of groundwater sampling procedures.

5.2 Well Gauging

Groundwater and NAPL, if present, elevation measurements shall be obtained in accordance with SOP SAS-08-01 or as otherwise specified in the Site-Specific Work and/or FSPs. Following sampling, the sampler may obtain the total well depth from top of casing (in feet to the nearest 0.01-foot) using a water level indicator, interface probe, or steel tape, as detailed in SOP SAS-08-05 and as required by the Site-Specific Work and/or FSP or otherwise specified. Measuring the total well depth prior to sampling should be avoided. Total well depths may be obtained following sampling activities or at least two weeks prior to the sampling. If total well depth is required to be measured immediately prior to sampling, the sampler will take precautions to minimize the displacement of sediments, if present, within the well during gauging activities. In general, the use of an interface probe shall be limited to wells containing NAPL or elevated concentrations of constituents of concern. Groundwater and NAPL elevation measurements and total well depth measurements shall be recorded in the field logbook and/or on the appropriate field form.

5.3 Pump/Tubing Intake Positioning

The sampler should determine and place or position the pump/tubing intake as appropriate relative to the position of the water level, screened interval, and constituents of concern. The position the pump/tubing intake should be a minimum of one foot above the well sump to the extent practical and preferably at an elevation near the center of the well screen. The sampler shall slowly raise or lower the pump or tubing when placing or positioning intake in order to minimize the displacement of sediments, if present, within the well. The pump model/type, tubing (type, inner diameter, and length), and pump/tubing intake depth/elevation shall be recorded in the field logbook and/or on the appropriate field form. If the water quality instruments can be programmed to calculate the one tubing volume, the data collected during pump/tubing intake placement/positioning shall be entered into the instrument. If the instrument cannot be programmed to calculate the tubing volume, this volume shall be calculated by the sampler using the following formula.

Tubing Volume $_{\text{(Gallons)}}$ = Tubing Length $_{\text{(Feet)}}$ x Volume per One Foot of Tubing $^{\text{TDS}}$ $_{\text{(Gallons/Foot)}}$

Where: $^{\text{TDS}}$ = Tubing inner diameter-specific; tubing manufacturer provided information.

The calculated tubing volume shall also be recorded in the field logbook and/or on the appropriate field form.

5.4 Equipment Assembly and Calibration

The sampler shall connect the tubing from the well to the inflow fitting at the bottom of the flow-through cell. A length of tubing shall be connected to the outflow fitting at the top of the flow-through cell with the other end extending into a 5-gallon bucket. The 5-gallon bucket shall be used to collect the purge water. Groundwater quality/indicator parameter monitoring instruments will be calibrated in accordance with the instrument operation manual(s) and SOP SAS-02-01 using the manufacturer prescribed calibration standards. During instrument calibration, the instrument shall be set up to measure and record data in the units (e.g. microsiemens per centimeter (uS/cm), milligrams per liter (mg/L), etc.) specified in the Site-Specific Work and/or Sampling Plan(s). Calibration shall be documented in the field logbook and/or on the appropriated field form. Following calibration, the instruments shall be connected to the flow-through cell.

5.5 Flow Rate and Drawdown Determination

The sampler shall re-gauge the depth to groundwater from the top of well casing. The sampler shall turn on the pump at its lowest setting and determine the flow rate by measuring the volume of water removed over a one-minute period using a graduated cylinder and stop watch or other approved flow rate measuring device. The sampler shall monitor the water column drawdown and shall adjust the pump to avoid a drawdown of more than 0.1 meter or 0.3 feet (4 inches). The flow rate of the pump shall generally be adjusted to between 0.2 and 0.5 liters per minute (L/min). During pump start-up, drawdown may exceed 0.3 feet provided the drawdown stabilizes and the groundwater level does not fall below the intake level. The water level shall not fall below the top of the well screen if the water level was greater than 0.5 feet above the well screen prior to commencing pumping activities. Pump adjustments shall be made within the first 15 minutes of purging. The final flow rate and stabilized drawdown shall be recorded in the field logbook and/or on the appropriated field form.

5.6 Purging and Groundwater Quality/Indicator Parameter Monitoring

The Site-Specific Work and/or FSPs shall specify the groundwater quality/indicator parameters to be monitored, which typically include temperature, pH, specific conductance or actual conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity. Parameter monitoring will begin after a minimum of tubing volume has been purged from the well. The sampler shall monitor and record in the field logbook and/or on the appropriate field form parameters every three to five minutes (during continuous purging) until parameters have stabilized. A generic groundwater sampling field form is provided in Appendix B. Five-minute intervals are typical; three-minute intervals are used during flow rates in highly permeable media that will allow pumping rates that exceed typical low-flow rates. Parameter stabilization is considered to be achieved when three consecutive readings, spaced approximately 2 to 10 minutes, or 0.5 well volumes or more apart, are within the parameter-specific limit listed in the table below or as specified in the Site-Specific Work and/or Sampling Plan(s).

Parameter	Stabilization Criteria[1]
Conductance, Specific Electrical	+/- 3% µS/cm @ 25°C
Conductivity, Actual[2]	+/- 3% µS/cm
Dissolved Oxygen	+/- 0.3 mg/L
Oxidation-Reduction Potential	+/- 10 mV
pH	+/- 0.1 standard units
Temperature	+/- 0.1 °C
Turbidity	≤10 NTUs or ± 10% when turbidity is greater than 10 NTUs and/or visually clear water

[1] USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001
[2] Based on the stabilization criteria for specific electrical conductance as published in the documented cited above

Once the parameters have stabilized, purging is considered complete and sample collection shall commence.

5.7 Sample Collection

While water is being purged from the well, groundwater samples shall be collected directly into the laboratory provided sample containers from the tubing, before the water has passed through the flow-through cell. This shall be accomplished by using a by-pass assemble or disconnecting the flow-through cell to obtain the sample. Water collected for analysis requiring field filtration will be filtered with an in-line Nalgene© disposable 0.45 micron (µm) filter, or equivalent. Water will be discharged directly from the in-line filter into the sample container following a filter pre-rinse, which will be performed by passing water through the filter, minimum of 500 milliliter (mL), and discharging prior to collection of the sample(s). Samples collected with bailers will be collected in intermediated unpreserved laboratory-provided containers and immediately field filtered as previous described with in-line filters.

Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSPs:

- Volatile organic compounds (VOCs);
- Semi-volatile organic compounds (SVOCs);
- Non-filtered, non-preserved samples (e.g. PCBs, sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered, non-preserved samples;
- Filtered, preserved samples (e.g. dissolved metals); and
- Miscellaneous parameters.

Quality Control (QC) samples, if required, will be collected consecutively to ensure appropriate duplicate sample collection in accordance with SOP SAS-04-03. Immediately following collection, samples shall be placed in an iced cooler.

5.8 Post-Sample Collection

Non-Dedicated and dedicated sampling equipment, which does not remain within the well casing, shall be removed from the monitoring well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP SAS-04-04 or as otherwise specified by the Site-Specific Work and/or Sampling Plan(s). Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work and/or FSPs. The sampler shall secure the well casing using a slip or expandable well cap. The flush-mount lid shall be bolted down or the protective cover closed and locked, as appropriate.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSPs. A generic groundwater sampling field form is provided in Appendix B.

7.0 REFERENCES AND ADDITIONAL RESOURCES

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

Author: J. Sapp Q2R & Approval By: A. Bazan / T. Gilles Q3R & Approval By: M. Kelley

STANDARD OPERATING PROCEDURE
NO. SAS-08-03

WELL-VOLUME APPROACH GROUNDWATER SAMPLING
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for obtaining groundwater samples using the well-volume approach from groundwater monitoring wells, recovery wells, or observation wells as described in the Site-Specific Work Plan or as otherwise specified for the purpose of determining groundwater quality. The well-volume approach involves the purging of the stagnant water within the well and stabilization of water quality indicator parameters prior to sampling.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (e.g. electronic water level indicator, interface probe, or weight steel tape);
- Well construction information, as appropriate;
- Calculator / Conversion Chart
- Pump, if required by the Site-Specific Work and/or Field Sampling Plan (FSP);
- Teflon®, polyvinyl chloride (PVC), or polypropylene pump-specific tubing, if applicable;
- Power Source, if applicable;
- Bailer – Disposable (disposable for purging and sampling), PVC (for purging only), and/or stainless steel (for purging and/or sample collection), if required by the Site-Specific Work and/or FSP;
- Rope, if applicable;
- Disposable plastic cups or stainless steel cup;
- Groundwater quality/indictor parameter monitoring instruments;
- Instrument operation manual(s);
- Instrument calibration standard(s);

- Container(s) for purge water volume measurements and storage (e.g. 5-gallon bucket, polyethylene storage tank, etc.);
- Sample containers and labels, as appropriate for the analytical method(s) selected;
- Field filtration equipment, if applicable;
- Chain of custody forms and seals;
- Cooler(s) with double-bagged ice;
- Polyethylene sheeting, as appropriate;
- Personal protective equipment;
- Decontamination materials and supplies;
- Field logbook and/or appropriate field form; and

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 APPLICATION

The well-volume approach is one of several acceptable sampling procedures. The well-volume approach involves the purging of the stagnant water within the well and stabilization of water quality indicator parameters prior to sampling. While this method can be used in wells screened in any formation, it is generally used to sample low-permeability formations (i.e., low-yielding wells).

Newly constructed and developed wells shall be allowed a minimum of 48 to72 hours to stabilize before sampling is performed. Once a well is purged, it should be sampled within 2 hours. If a purged well is allowed to sit longer than the prescribed 2 hours the water contained in the well casing may no longer be representative of aquifer conditions and the well shall be re-purged with one exception. If a water table well is purged dry, it should be sampled when a sufficient volume of water is present. In general, the sample collection shall take place within 24 hours of bailing or pumping the well dry. Purging a water table well dry should be avoided if possible. Wells screened below the water table should never be purged dry. Purging wells screened across water table must be performed at a rate that prevents significant reduction in the water table elevation. Wells that are purged dry should be sampled at least 2 hours after purging activities. Sampling of wells that are known to contain NAPL will follow procedures in SOP SAS-08-07.

5.0 EXECUTION

To the extent practical, sampling shall begin at the monitoring well with the least contamination and proceed systematically to the monitoring wells with the most contamination using the procedure outlined in the following subsections unless otherwise required by the Site-Specific Work and/or FSPs.

5.1 Preparation

The sampler shall create a work area around the monitoring well to minimize the potential for cross-contamination. Work area preparations may include the placement of polyethylene sheeting prevent sampling equipment from coming in contact with the ground surface. The sampler shall barricade and/or flag the work area, if required by the Site-Specific HASP. The sampler shall also arrange the sampling equipment and supplies to facilitate efficient execution of groundwater sampling procedures.

5.2 Well Gauging

Groundwater and non-aqueous phase liquid (NAPL), if present, elevation measurements shall be obtained in accordance with SOP SAS-08-01 or as otherwise specified in the Site-Specific Work and/or FSP. The sampler shall also obtain the total well depth from top of casing (in feet to the nearest 0.01-foot) using a water level indicator, interface probe, or steel tape, as required by the Site-Specific Work and/or FSP or otherwise specified. Total well depths may be obtained prior to the sampling and provided to the sampler. If total well depth is required to be measured immediately prior to sampling, the sampler will take precautions to minimize the displacement of sediments, if present, within the well during gauging activities. In general, the use of an interface probe shall be limited to wells containing NAPL or elevated concentrations of constituents of concern. Groundwater and NAPL elevation measurements and total well depth measurements shall be recorded in the field logbook and/or on the appropriate field form.

5.3 Standing Water Column Calculation

The sampler shall calculate the standing water column using the following formula:

Standing Water Column $_{\text{(Feet)}}$ = TD $_{\text{(FT BTOC)}}$ – DTW $_{\text{(FT BTOC)}}$

Where: TD = Total Well Depth
FT BTOC = Feet below top of well casing
DTW = Depth to Water

The sampler shall record the calculation in the field logbook and/or on the appropriate field form.

5.4 Volume Calculations

The sampler shall calculate the volume of water required to be purged prior to sampling. Depending on data quality objectives, state- or regulatory program-specific requirements, and the Site-Specific Work and/or FSP, one of two methods may be used: casing volume or borehole volume. In general, a minimum of three volumes of water, casing or borehole, shall be purged prior to sample collection (see section 5.6 below) in addition to stabilization of groundwater quality indicator parameters.

5.4.1 Casing Volume Calculation:

The sampler shall calculate the casing volume, which is the volume of water inside the well casing only, using the following formula.

One Casing Volume $_{\text{(Gallons)}}$ = Standing Water Column $_{\text{(Feet)}}$ X Volume per One Foot of Casing $^{\text{WDS}}{}_{\text{(Gallons/Foot)}}$

Where: $^{\text{WDS}}$ = Well diameter-specific (see table below)

Well Diameter-Specific Volume Per One Foot of Casing				
Well Diameter (Inches)	**Volume Per Foot of Casing (Gallons)**		**Well Diameter (Inches)**	**Volume Per Foot of Casing (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469

Well Diameter-Specific Volume Per One Foot of Casing				
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

The sampler shall record the calculation in the field logbook and/or on the appropriate field form.

5.4.2 Borehole Volume Calculation

The sampler shall calculate the borehole volume, which is the volume of water inside the well casing and volume of water inside the filter pack, using the following formula. Please note that this calculation requires the sampler to know the borehole diameter, filter pack height/elevation, and filter pack porosity.

One Borehole Volume $_{(Gallons)}$ = n ((A X B) – (A X C)) + (C X D)

Where: n = porosity of the filter pack (generally assumed to be 25% or 0.25)

A = height (in feet) of saturated filter pack

B = borehole diameter-specific volume (see table below)

C = well diameter-specific volume (see table below)

D = standing water column (see Section 5.4.1 above)

Diameter-Specific Volume Per One Foot of Borehole or Casing				
Diameter (Inches)	**Volume Per Foot of Borehole or Casing (Gallons)**		**Diameter (Inches)**	**Volume Per Foot of Borehole or Casing (Gallons)**
0.25	0.0026		4.0	0.6528
0.50	0.0102		6.0	1.469
0.75	0.0230		8.0	2.611
1.0	0.0408		10.0	4.081
2.0	0.1632		12.0	5.876

The sampler shall record the calculation in the field logbook and/or on the appropriate field form.

5.5 Equipment Assembly and Preparation

5.5.1 Pumps

Extreme caution should be exercised to ensure that the equipment does not cause cross-contamination from one well to the next. Therefore, dedicated tubing and pumps are preferred. Peristaltic pumps may be used when the well depth is less than or equal to fifteen feet, in zones of high contamination, or as approved in a SSWP. If it is not practical to dedicate a pump to a specific well, the pump shall be decontaminated in accordance with SOP ENV-04-04. Tubing should always be dedicated and never used for more than one well.

The sampler shall place or position the pump/tubing intake not greater than 6 feet below the dynamic water level in the well and a minimum of one foot above the well sump to the extent practical. Ideally, in non-water table wells, the pump shall be placed within the well screen section. The sampler shall slowly raise or lower the pump or tubing when placing or positioning intake in order to minimize the displacement of sediments, if present, within the well. The pump model/type, tubing (type, inner diameter, and length), and pump/tubing intake depth/elevation shall be recorded in the field logbook and/or on the appropriate field form.

5.5.2 Bailers

Bailers will be used for sampling activities when site-specific work plans provide rational and justification for the use. If a non-dedicated PVC and/or stainless steel bailer(s) is/are used, the bailer(s) must be decontaminated in accordance with SOP ENV-04-04 prior to well purging. The bailer shall be secured using rope to a purge water storage container, protective cover, flush-mount lid, or other object such that the bailer can be retrieved from the well. The rope that will enter the well casing shall not come in with the ground. Bailer samples will be collected using bottom valve sampling devices to limit sample aeration.

5.6 Purging and Groundwater Quality/Indicator Parameter Monitoring

The Site-Specific Work and/or FSP shall specify the groundwater quality/indicator parameters to be monitored, which typically include temperature, pH, specific conductance or actual conductivity, oxidation-reduction potential, dissolved oxygen, and turbidity. Parameter monitoring will begin after a minimum of one volume, casing or borehole (as specified by the Site-Specific Work and/or FSP) has been purged from the well. The sampler shall monitor and record in the field logbook and/or on the appropriate field form parameters a minimum of every well volume until parameters have stabilized. A generic Groundwater Sampling Field Form is provided in Appendix B. When pumps are utilized for purging, stabilization parameters will be monitored with a flow through cell in accordance with SOP SAS-08-02. Parameter stabilization is considered to be achieved when three consecutive readings, taken every well volume with bailer purging, are within the parameter-specific limit listed in the table below or as specified in the Site-Specific Work and/or FSP and a minimum of three volumes, casing or borehole (as specified by the Site-Specific Work and/or FSP), have been evacuated from the well or the well is purged dry, whichever occurs first. Purging methods are discussed in Sections 5.6.1 and 5.62 below.

Parameter	**Stabilization Criteria**[1]
Conductance, Specific Electrical	+/- 3% µS/cm @ 25°C
Conductivity, Actual[2]	+/- 3% µS/cm
pH	+/- 0.1 standard units
Dissolved Oxygen	+/- 0.3 mg/L
Oxidation-Reduction Potential	+/- 10 mV
Temperature	+/- 0.1 °C
Turbidity	<u><</u>10 NTUs or ± 10% when turbidity is greater than 10 NTUs and/or visually clear water

Once the parameters have stabilized and a minimum of three volumes, casing or borehole (as specified by the Site-Specific Work and/or FSP), have been evacuated from the well or the well is purged dry, sample collection shall commence (see Section 5.7 below).

5.6.1 Pumps

Following pump/tubing intake placement, the sampler shall commence with purging by turning on the pump. During pumping, intermittently collect pump discharge in a container of known volume for a period of not less than 1 minute to determine the pump flow rate. The approximate pump flow rate shall be documented in the field logbook and/or on the appropriate field form. The sampler shall monitoring groundwater quality/indicator parameters, as described in above, preferably using a flow through cell in accordance with

[1] USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, EPA 542-S-02-001

[2] Based on the stabilization criteria for specific electrical conductance as published in the documented cited above

SOP SAS-08-03. Groundwater quality/indicator parameters shall be recorded in the field logbook and/or on the appropriate field form along with the time and volume of water purged (to the gallon). Periodic measurements of the flow rate will also be recorded during sampling. The evacuated/purged water shall be containerized in an approved storage container as required by the Site-Specific Work and/or FSP.

5.6.2 Bailers

The sampler shall slowly lower and raise the bailer in the well in order to minimize the displacement of sediments, if present, within the well. The sampler shall monitoring groundwater quality/indicator parameters by collecting bailer discharge in a disposable plastic cup, stainless steel cup, or other manner befitting the monitoring instruments (e.g., down-hole probe). Groundwater quality/indicator parameters shall be recorded in the field logbook and/or on the appropriate field form along with the time and volume of water purged. The evacuated/purged water shall be containerized in an approved storage container as required by the Site-Specific Work and/or FSP.

5.7 Sample Collection

5.7.1 Pumps

In general, groundwater samples shall only be collected from adjusted rate peristaltic pumps or adjustable rate low-flow submersible or positive displacement pumps. Groundwater samples shall be collected directly into the laboratory provided sample containers from the tubing, before the water has passed through the flow-through cell. This shall be accomplished by using a by-pass assemble or disconnecting the flow-through cell to obtain the sample. Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSP:

- Volatile organic compounds (VOCs);
- Semi-volatile organic compounds (SVOCs);
- Non-filtered, non-preserved samples (e.g. Polychlorinated biphenyls (PCBs), sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered (reference SAS-SOP-08-02), non-preserved samples;
- Filtered (reference SAS-SOP-08-02), preserved immediately samples (e.g. dissolved metals); and
- Miscellaneous parameters.

Immediately following collection, samples shall be placed in a cooler with double-bagged ice.

5.7.2 Bailers

In general, groundwater samples shall only be collected from disposable or stainless steel bailers, when pumps are not applicable for sample collection (e.g., low-yielding wells). Groundwater samples shall be collected directly into the laboratory provided sample containers from the bailer. Samples shall be collected in order of analyte stability, as summarized below, unless otherwise specified by the Site-Specific Work and/or FSP:

- VOCs;
- SVOCs;
- Non-filtered, non-preserved samples (e.g. PCBs, sulfate, etc.);
- Non-filtered, preserved samples (e.g. phenols, nitrogen, cyanide, total metals, etc.);
- Filtered (reference SAS-SOP-08-02), non-preserved samples;
- Filtered, (reference SAS-SOP-08-02) preserved samples (e.g. dissolved metals); and
- Miscellaneous parameters.

Immediately following collection, samples shall be placed a cooler with double-bagged ice.

5.7.3 Quality Control Samples

Quality Control (QC) samples, if required, will be collected consecutively to ensure appropriate duplicate sample collection in accordance with SOP SAS-04-03. Immediately following collection, samples shall be placed in a cooler with double-bagged ice.

5.8 Post-Sample Collection

Non-dedicated and dedicated sampling equipment, which does not remain within the well casing, shall be removed from the monitoring well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP SAS-04-04 or as otherwise specified by the Site-Specific Work and/or FSP. Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work and/or FSP. The sampler shall secure the well casing using a slip or expandable well cap. The flush-mount lid shall be bolted down or the protective cover lid closed and locked, as appropriate.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP SAS-03-01 and SAS-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP SAS-01-01 or as required by the Site-Specific Work and/or FSP. A generic Groundwater Sampling Field Form is provided in Appendix B.

7.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells

ASTM International, D5903-96(2001) Standard Guide for Planning and Preparing for a Groundwater Sampling Event

ASTM International, D6089-97(2003)e1 Standard Guide for Documenting a Ground-Water Sampling Event

ASTM International, D6301-03 Practice for the Collection of Samples of Filterable and Nonfilterable Matter in Water

ASTM International, D6452-99(2005) Standard Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations

ASTM International, D6564-00(2005) Standard Guide for Field Filtration of Ground-Water Samples

ASTM International, D6634-01 Guide for the Selection of Purging and Sampling Devices for Ground- Water Monitoring Wells

ASTM International, D6771-02 Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, 2002, Ground-Water Sampling Guidelines for Superfund and RCRA Project Manager, Region 5 and Region 10, EPA 542-S-02-001.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-08-04

AQUIFER TESTING
Revision 2

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for field evaluation of aquifer hydraulic conductivity. Variations in the hydraulic conductivity within or between formations or strata can create irregularities in groundwater flow paths. Formations of high hydraulic conductivity represent areas of greater groundwater flow and, therefore, zones of potential preferred contaminant migration. Further, anisotropy within strata or formations affects the magnitude and direction of groundwater flow. Thus, information on hydraulic conductivities is necessary to evaluate preferential flow paths and groundwater velocity.

Hydrogeologic assessments should contain data on the hydraulic conductivities of the significant formations underlying the site as measured in monitoring wells. It may be beneficial to use numerical or laboratory methods to augment results of field tests. However, field methods provide the best definition of the horizontal hydraulic conductivity in most cases. Field methods differ from laboratory methods which measure vertical hydraulic conductivity, typically in Shelby tube samples.

2.0 EQUIPMENT AND MATERIALS

- Pump (and generator if required) capable of withdrawal at a constant or predetermined variable rate that can meet the designed pumpage rate and lift requirements
- Water pressure transducers and data logger (bring transducers for the pumping well and each observation well as well as extras in case of malfunction)
- A flow meter or other type of water measuring device to accurately measure and monitor the discharge from the pumping well
- Sufficient hose or pipe to convey discharge outside the recharge area of the pumping well and observation wells
- Electric water level indicator(s) capable of measurement to the hundredth of a foot
- Watch or stopwatch with second hand

- Barometer (some groundwater multiprobes include a barometer)
- Tape Measure of appropriate length based on distance to observation wells.
- Flashlights, lanterns, alarm clock, electrical tape
- Semi-log graph paper, pens, and field book

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 FIELD METHODS

Varieties of procedures are available for evaluating hydraulic conductivity in the field. ASTM D4043-96(2004) Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques should be consulted in selecting an appropriate test method. Field methods for collecting hydraulic conductivity data are described in a number of ASTM standard practices:

- D2434-68(2000) Test Method for Permeability of Granular Soils (Constant Head)
- D4044-96(2002) Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
- D4050-96(2002) Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems
- D4104-96(2004) Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)
- D4105-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method

- D4106-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method
- D4511-00 Test Method for Hydraulic Conductivity of Essentially Saturated Peat
- D4630-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test
- D4631-95(2000) Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique
- D5269-96(2002) Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method
- D5270-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers
- D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well
- D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer
- D5720-95(2002) Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes
- D5785-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)
- D5786-95(2000) Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems
- D5850-95(2000) Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells
- D5855-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well
- D5881-95(2005) Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)
- D5912-96(2004) Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)

- D5920-96(2005) Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method
- D6028-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method
- D6029-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method
- D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability
- D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test
- D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

5.0 SINGLE WELL TESTS

Hydraulic conductivity can be determined in the field using a variety of test methods, each addressing specific conditions, and/or data collection objectives. These methods are commonly referred to as bail down or slug tests and are performed by adding or removing a slug (known volume of water or solid inert material) from a well and observing the recovery of the water surface to its original level. Similar results can be achieved by pressurizing the well casing, depressing the water level, and suddenly releasing the pressure to simulate removal of water from the well. One method is described by McLane, et. al. (1990) and is contained in references to the Standard Practices.

When reviewing information obtained from slug tests, several criteria should be considered. First, they are run on one well and, as such, the information is limited to the geologic area directly adjacent to the screen. Second, the vertical extent of screen will control the part of the geologic formation that the test analyzes. Portions of the geologic formation(s) above or below the screen and sand filter pack and seal intervals may also require separate hydraulic conductivity testing. Third, the methods used to collect single well test data should accurately measure parameters such as changing static water (prior to initiation, during, and following completion of the test), the amount of water removed from the well (or slug volume introduced), and the elapsed time of recovery. The use of pressure transducers and high speed recording equipment is critical in highly permeable formations.

Observation wells with screens that intersect the water table (i.e. water table wells) will be tested only by methods involving removal of water or a slug from the well in order to minimize the potential for well screen filter pack interference. The addition of water to any monitoring well shall be avoided whenever possible, since the addition may affect water quality in sampling events. When addition of water to a well is unavoidable, the water must be of documentable quality and three times the volume added to the well must be removed immediately upon completion of the test. Addition of water to an observation well is appropriate only to piezometer installation when the dynamic water level is above the well screen and sand filter pack and seal elevations.

Full development of the well screen and filter pack adjacent to the interval under examination, in accordance with SOP SAS-05-04, should be completed following well construction to ensure the removal of fines or correct deleterious drilling effects. Determination of well integrity, SOP SAS-08-05, should be determined prior to performance of the well test.

It is important that slug tests be of sufficient duration to provide representative measures of hydraulic conductivity. Slug tests will range in length from less than a minute to several hours. The time required for a test is a function of the volume of the slug added or removed the formation hydraulic conductivity, and well construction.

Slug tests should be performed at least twice to ensure the accuracy of data collection. General procedures for a slug test are summarized below. The procedures required for a slug test may vary, depending on site-specific-conditions. Modifications to the test procedures will be contained in site-specific work plans.

5.1 Slug Test Procedures with Pressure Transducer and Data Logger

An individual Slug Test Field Form (Appendix B) should be completed for each well tested and should contain at least:

- Project ID - A number assigned to identify a specific site.
- Well ID - The location of the well in which water level measurements are being taken.
- Personnel - The personnel conducting the pumping test.
- Measurement Methods - Type of pump, type of data logger(s) used to record water levels, transducer ID number, and acquisition rate (i.e. data recorded on a log scale). The transducer psi range should be appropriate to the test (e.g. 0 to 5 or 0 to 10 psi).
- Initial Static Water Level (Test Start) - Depth to water, to the nearest 0.01 feet, in the observation well at the beginning of the slug test.
- Slug Withdrawal / Addition Start Time - The date when the test began, and start time using a 24-hour clock.
- Test End Date/Time - The date and time when water level readings were discontinued.
- Final Static Water Level (Test End) - Depth to water, to the nearest 0.01 feet, in the observation well at the end of the slug test.
- Elapsed Time (min) - Time of manual measurement record from time 0.00 (start of test) recorded in minutes and seconds.
- Notes - Appropriate observations or information that has not been recorded elsewhere, including notes on sampling, pH readings, and conductivity readings.

Prior to commencing the slug test, enter site-specific information in the data logger per manufacturer instructions. Store all logger data internally; and on laptop computer and/or portable data key. The data should be transferred to the chosen backup storage device as soon as practical after the test is completed.

Water levels should be measured as specified in the SOP SAS-08-02. Manual measurements are required as a backup to and verification of the data logger(s). It is critical that depth to water readings be measured accurately and the exact time of readings is recorded. Determine the static water level in the well; measure the depth to water periodically for several minutes to several hours, and taking the average of the readings (see SOP SAS-07-02). Record information on the Slug Test Field Form (Attachment B). Additional information should be recorded on the Daily Activity Log in SOP SAS-01-04.

5.2 Slug Test Preparation

- Lower the transducer and cable in the well below the estimated target drawdown depth, ensuring the depth of submergence is within the transducer design range.
- Tape the transducer cable to the exterior of the well casing or protective cover to hold the transducer at a constant depth
- Connect the transducer cable to the data logger.
- Check the transducer accuracy by raising and lowering the transducer and comparing the change in water level from the transducer reading to the distance the transducer is raised or lowered.
- Enter the initial water level and transducer design range into the recording device according to the manufacturer's operating instructions.
- Allow the static water level to equilibrate to within 0.1 feet of the initial water level.

5.3 Slug Test with Transducer Procedure

- Turn the data logger on and begin collecting data points.
- Smoothly lower the slug/bailer into the well and allow the water level to stabilize within 0.1 feet of the initial water level.
- Remove the slug/bailer as quickly and smoothly as practical. A smooth, rapid removal is required as slug test analysis assumes an instantaneous change in volume is created in the well when the slug is removed.
- The moment the volume is removed is time zero. Collect hand measured water level measurements (Table 1) as a data backup and to verify transducer data.
- Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to show a trend on a plot of water level recovery versus the logarithm of time in accordance with the chosen analysis method. Time will range from less than 1 minute to a few hours.
- Repeat the slug test once the static water level has recovered to within 95 % of the original water level.

Table 1: Time Intervals for Measuring Recovery in Slug Test Well

Elapsed Time Since Start or Stop of Test (Minutes)	OR (which ever is greater)	Percent Water Level Recovery (%)	Interval Between Measurements (Minutes)
0-2		0-30	0.1
2-5		30-50	0.5
5-10		50-60	1
10-60		60-70	5
60-120		70-80	10
120-240		80-100	30

5.4 Slug Test with Water Level Meter

This slug test method should only be used if a transducer/data recorder cannot be obtained or are malfunctioning. This method cannot be used for saturated zones with high hydraulic conductivities because stabilization of groundwater will occur rapidly. Slug test data should be recorded on the Slug Test Data form (Attachment B) in accordance with the completion instructions. Follow the same procedures for Slug Test with Transducer with increased data collection frequency.

Table 2: Time Intervals for Measuring Recovery in Slug Test Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-2	0.1
2-10	0.5
10-30	1
30-60	5
60-120	10
120-240	30

The interpretation of the single well test data should be consistent with the existing geologic information (boring log data). Staff should be aware of initial rapid water level recovery during a slug test may represent drainage of the filter pack material around the well screen. This is of particular concern in wells screened in low hydraulic conductivity formations (e.g. silty clay, shale). These data points should be ignored when selecting the appropriate data points to establish a water level recovery slope.

6.0 MULTIPLE WELL TESTS

Multiple well tests, more commonly referred to as pumping tests, are performed by pumping water from one well and observing the resulting drawdown in nearby wells. Tests conducted with wells screened in the same water-bearing formation provide hydraulic conductivity data. Tests conducted with wells screened in different water-bearing zones furnish information concerning hydraulic communication between units. Multiple well tests for hydraulic conductivity are advantageous because they characterize a greater proportion of the subsurface and thus provide a greater amount of detail. Multiple well tests are subject to similar constraints to those listed above for single well tests. Some additional problems that should have been considered in conducting a multiple well test include: (1) storage of potentially contaminated water pumped from the well system, and (2) potential effects of groundwater pumping on existing waste plumes. The geologic constraints should be considered to interpret the pumping test results. Incorrect assumptions regarding geology may translate into incorrect estimations of hydraulic conductivity.

7.0 LABORATORY METHODS

Laboratory analysis of undisturbed samples (e.g. Shelby tube) provides values of vertical hydraulic conductivity. When laboratory methods are to be used, the specific ASTM Standard Practice shall be referenced in samples provided to subcontractors. ASTM methods shall be consulted to assure that test methods specified are applicable to the sample to be tested.

8.0 CONTROLLED PUMPING TESTS

The most representative method for determining aquifer characteristics is by controlled aquifer pumping tests, because these tests stress a much larger volume of the formation than slug tests and laboratory tests. Pumping tests require a higher level of effort and expense than other types of aquifer tests, and are not always justified.

As an example, slug tests may be acceptable for site characterization, whereas pumping tests may be performed to support remedial design or modeling.

Aquifer characteristics that may be obtained from pumping tests include transmissivity (T), hydraulic conductivity (K), specific yield (Sy) for unconfined aquifers, and storage coefficient (S) for confined aquifers. These parameters can be determined by graphical solutions and computerized programs, such as Aqtesolv®.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required dependent on site conditions, equipment limitations, or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

8.1 Summary

If possible, continuously monitor pre-test water levels at the test site for about one week prior to performance of the pump test. This information allows for the determination of the barometric efficiency of the aquifer, as well as noting changes in head due to recharge or pumping in the area adjacent to the well. Prior to initiating the long-term pump test, a step test (Section 5.5) is performed to estimate the greatest flow rate that may be sustained by the pump well.

After the pumping well has recovered from the step test, the long-term pumping test begins. At the beginning of the test, the discharge rate is set as quickly and accurately as possible. The water levels in the pumping well and observation wells are recorded following a set schedule. The duration of the test is determined by project needs and aquifer properties; typically three days or until water levels becomes constant.

8.2 Interferences and Potential Problems

Prior to conducting a pumping test, efforts should be made to anticipate and resolve interferences and potential problems that could affect the aquifer or the test. These problems could be caused by changing atmospheric conditions, impact of local potable wells, contaminants in the aquifer, etc. Note that if it is necessary for a neighboring well to pump during the test, pumping should commence as early as feasible prior to start of the test at a constant rate and not started or stopped for the duration of the test.

8.3 Pumping Discharge

If a pumping test will be conducted in an area with contaminated groundwater, special arrangements must be made for proper handling, treatment, and disposal of the water. The preferred method is to discharge to a sanitary sewer, with prior approval.

Uncontaminated groundwater discharge generated during a pumping test should be sent to storm or sanitary sewers, abiding by all applicable regulations. If there are no sewers in the vicinity of the pumping well, the discharge may be sent to a river or pond. If the previously mentioned discharge options are not available, the groundwater may be discharged to the ground surface under either of the following conditions:

- The aquifer being tested is confined; or
- The end of the discharge hose/pipe is outside of the cone of depression created by the pumping well when testing an unconfined aquifer.

8.4 Pre-Test Procedures

The hydrostratigraphy of the aquifer should be fully characterized prior to performance of the test to identify formation thickness, whether it is confined or unconfined, whether confining layers are leaky and to identify any lateral boundaries that may influence results.

If the pumping test occurs at a site where existing production and/or monitoring wells will be used, confirm that the locations and screened intervals of the wells are within the same aquifer, and meet the requirements of the method of analysis.

If possible, continuously measure water levels in the pumping well and all observation wells for a period at least equal to the length of the test. Trends should be similar in all wells. A well with an unusual trend may indicate some local stress in the aquifer.

The magnitude of water-level fluctuations due to changes in barometric pressure will change throughout the test and should be adjusted based on the changes in the barometric pressure recorded during the test. Changes in barometric pressure will be recorded during the test in order to correct water levels for any possible fluctuations that may occur due to changing atmospheric conditions. These barometric changes are used to "correct" water levels during the test so they are representative of the hydraulic response of the aquifer due to pumping of the test well. Ideally, water levels should be measured in a well outside of the cone of depression before, during, and after pumping to determine background changes in water levels during the test and to establish correction factors for the wells within the cone of depression.

8.5 Step Test

The step drawdown test is performed to determine the maximum pumping rate that the pumping well can sustain and the minimum pumping rate necessary to assure drawdown in the observation wells. The pumping and observation wells are equipped with transducers prior to the test. Check the transducer accuracy by raising and lowering the transducer and comparing the change in water level from the transducer reading to the distance the transducer is raised or lowered.. The test is then performed by pumping at a low rate, relative to the expected final rate of pumpage, until drawdown in the pumping well stabilizes. The rate is then increased again until drawdown in the pumping well stabilizes (step 2). A minimum of three steps will be tested; the duration of each step will be similar, and should be between 30 minutes and 2 hours.

The data are then plotted on semi-log paper or on a computer. The maximum sustainable pumping rate that yields drawdown in the closest observation wells will be used as the target-pumping rate for the long-term test. These data may also be used to determine aquifer properties and well loss in the pumping well.

8.6 Pump Test Time Intervals

Commence the long-term pumping test after the pumping well has fully recovered from the step test. Place transducers into the observation wells prior to starting the test and allow time for them to equilibrate to the water temperature within the well and to collect pre-test water level data. At the beginning of the test, the discharge rate should be set as quickly and accurately as possible. Record the pumping and observation well water levels with transducers and a data logger(s) set to record logarithmically. As backup in case of transducer malfunction, manually record water levels on field forms and/or field notebooks according to the schedules in Tables 3 and 4:

Table 3: Time Intervals for Measuring Drawdown in the Pumped Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-10	0.5-1
10-15	1
15-60	5
60-300	30
300-1440	60
1440-termination	480

Table4: Time Intervals for Measuring Drawdown in an Observation Well

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-60	2
60-120	5
120-240	10
240-360	30
360-1440	60
1440-termination	480

For wells with a transducer malfunction, water levels records should be manually recorded on field forms and/or field notebooks according to the schedule in Table 5:

Table 5: Time Intervals for Measuring Drawdown in the Observation Wells with Transducer Malfunction

Elapsed Time Since Start or Stop of Test (Minutes)	Interval Between Measurements (Minutes)
0-2	0.1
2-10	0.5
10-20	1
20-100	5
100-200	10
200-300	30
300-1440	60
1440-termination	480

8.7 Water Level Measurements

Water levels will be measured as specified in the SAS-08-02. During the early part of the test, sufficient personnel are required to initiate the pumping test data loggers and assist with manual water level measurements of the pumping well and flow rate measurements. Manual measurements are required as a backup to and verification of the data logger(s). After the first two hours, one to two people are usually sufficient to continue the test. It is not necessary that readings at the wells be taken simultaneously. It is very important that depth to water readings be measured accurately and the exact time of readings is recorded.

During a pumping test, the following data must be recorded accurately on the log book and/or the aquifer test data form.

- Project ID - A number assigned to identify a specific site.
- Well ID - The location of the well in which water level measurements are being taken.
- Distance and Direction from Pumped Well - Distance and azimuth to each observation well from the pumping well in feet.
- Personnel - The personnel conducting the pumping test.

- Pumping Start and End Date/Time - The date when the pumping began, and start time using a 24-hour clock.
- Initial Static Water Level (Test Start) - Depth to water, to the nearest 0.01 feet, in the observation well at the beginning of the pumping test.
- Test End Date/Time - The date and time when water level readings were discontinued.
- Final Static Water Level (Test End) - Depth to water, to the nearest 0.01 feet, in the observation well at the end of the pumping test.
- Target Pumping Rate
- Measurement Methods - Type of pump, type of data logger(s) used to record water levels, transducer ID number, and acquisition rate (i.e. data recorded on a log scale). The transducer psi range should be appropriate to the test (e.g. 0 to 5 or 0 to 10 psi).
- Notes - Appropriate observations or information that has not been recorded elsewhere, including notes on sampling, pH readings, and conductivity readings.
- Elapsed Time (min) - Time of manual measurement record from time 0.00 (start of test) recorded in minutes and seconds.
- Depth to Water (ft) – Manual depth to water measurement, to the nearest 0.01 feet, in the observation well at the time of the water level measurement.
- Flow Rate (gal/min) - Flow rate of pump measured from an orifice, weir, flow meter, container, or other type of water measuring device.

8.8 Pump Test Duration

The duration of the test is determined by the needs of the project and properties of the aquifer. One simple test for determining adequacy of data is when the log-time versus drawdown for the most distant observation well begins to plot as a straight line on the semi-log graph paper. There are several exceptions to this simple rule of thumb; therefore, it should be considered a minimum criterion. Different hydrogeologic conditions can produce straight-line trends on log-time versus drawdown plots. In general, longer tests produce results that are more definitive. Duration of one to three days is desirable, followed by a similar period of monitoring the recovery of the water level. Unconfined aquifers and partially penetrating wells may have shorter test durations. Knowledge of the local hydrogeology, combined with a clear understanding of the overall project objectives is necessary in judging appropriate test duration. There is no need to continue the test once the water levels in the observation wells stabilize.

The recovery of water levels following pumping phase may be measured and recorded for a period equal to the pumping phase. The frequency of the water level measurements should be similar to the frequency of water level measurements during the pumping phase (Table 1).

9.0 POST OPERATION

The following activities are performed after completion of water level recovery measurements following a slug or pumping/recovery test:

- Decontaminate and/or dispose of equipment per SAS-04-05.
- When using an electronic data-logger, use the following procedures:
  - Stop logging sequence
  - Check file size, print data, and/or save memory to a reliable storage device (i.e. hard drive or USB drive): Backup the data as soon as possible upon completion of a test!
  - Do not clear the memory of the transducer until the data has been saved onto a hard drive
- Review field forms for completeness.
- Replace testing equipment in storage containers
- Check sampling equipment and supplies. Repair or replace all broken or damaged equipment.
- Interpret slug or pumping/recovery test field results.

10.0 CALCULATIONS

Upload the data from the test into a spreadsheet to be entered into a computerized program, such as Aqtesolv®. Use the information entered into the Data Acquisition Form to complete the computer analysis of the data. There are several accepted methods for determining aquifer properties such as transmissivity, storativity, and conductivity. The appropriate method to use is dependent on the characteristics of the aquifer being tested (confined, unconfined, leaky confining layer etc.). When reviewing slug and pump test data, the following text and/or documents may be used to determine the method most appropriate to your case:

- Analysis and Evaluation of Pumping Test Data (Kruseman and Ridder, 1989)
- Applied Hydrogeology (Fetter, 2000)

- Groundwater and Wells (Driscoll, 1986)
- ASTM D4105-96(2002)
- ASTM D4106-96(2002)

11.0 QUALITY ASSURANCE/ QUALITY CONTROL (QA/QC)

Gauges, transducers, flow meters, and other equipment used in the pumping tests will be calibrated before use at the site. Copies of the documentation of instrumentation calibration will be filed with the test data records. The calibration records will consist of laboratory measurements and, if necessary, any on-site zero adjustment and/or calibration that were performed. Where possible, all flow and measurement meters will be checked on-site using a container of measured volume and stopwatch; the accuracy of the meters must be verified before testing proceeds. For QA/QC purposes, a minimum of two single well tests (slug test) should be performed in each well that hydraulic conductivity testing is performed.

12.0 DATA REDUCTION AND INTERPRETATION

Slug and multiple well test data can be analyzed by a variety of methods, depending on the responses observed, geologic conditions, and specific well parameters. Texts such as Driscoll (1986) or other well hydraulics references should be consulted for selection of the proper method of data analysis. In reviewing hydraulic conductivity measurements, the following criteria should be considered to evaluate the accuracy or completeness of information.

- Values of hydraulic conductivity between wells in similar lithologies should generally not exceed one order of magnitude difference.
- Hydraulic conductivity determinations based upon multiple well tests are preferred. Multiple well tests provide more complete information because they characterize a greater portion of the subsurface.
- Use of single well tests will require that more individual tests be conducted at different locations to sufficiently define hydraulic conductivity variation across the site.
- Hydraulic conductivity information generally provides average values for the entire area across a well screen. For more depth discrete information, well screens will have to be shorter. If the average hydraulic conductivity for a formation is required, entire formations may have to be screened, or data taken from overlapping clusters.

It is important that measurements define hydraulic conductivity both vertically and horizontally across the site. Laboratory tests may be necessary to ascertain vertical hydraulic conductivity in saturated formations or strata. Results from boring logs should also be used to characterize the site geology. Zones of high permeability or fractures identified from drilling logs should be considered in the determination of hydraulic conductivity. Additionally, information from boring logs can be used to refine the data generated by single well or pumping tests.

13.0 REFERENCES AND ADDITIONAL RESOURCES

Bouwer, H., and Rice, R.C., "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with completely or Partially Penetrating Wells", Water Res. Res., 12 p. 423-428, 1976.

Driscoll, F. G., 1986, Groundwater and Wells, Johnson Division, St. Paul, MN, 1089 p.

McLane, G. A., D. A. Harrity, K. O. Thomsen, "Slug Testing In Highly Permeable Aquifers Using a Pneumatic Method", Hazardous Materials Control Research Institute, Conference Proceedings, November, 1990, pp 300-303.

ASTM International, D2434-68(2000) Test Method for Permeability of Granular Soils (Constant Head)

ASTM International, D4043-96(2004) Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques

ASTM International, D4044-96(2002) Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers

ASTM International, D4050-96(2002) Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems

ASTM International, D4104-96(2004) Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)

ASTM International, D4105-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method

ASTM International, D4106-96(2002) Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method

ASTM International, D4511-00 Test Method for Hydraulic Conductivity of Essentially Saturated Peat

ASTM International, D4630-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test

ASTM International, D4631-95(2000) Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique

ASTM International, D5269-96(2002) Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method

ASTM International, D5270-96(2002) Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers

ASTM International, D5472-93(2005) Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well

ASTM International, D5473-93(2000) Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer

ASTM International, D5720-95(2002) Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes

ASTM International, D5785-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)

ASTM International, D5786-95(2000) Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems

ASTM International, D5850-95(2000) Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells

ASTM International, D5855-95(2000) Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well

ASTM International, D5881-95(2005) Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)

ASTM International, D5912-96(2004) Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)

ASTM International, D5920-96(2005) Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method

ASTM International, D6028-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method

ASTM International, D6029-96(2004) Test Method (Analytical Procedure) for Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method

ASTM International, D6030-96(2002) Guide for Selection of Methods for Assessing Groundwater or Aquifer Sensitivity and Vulnerability

ASTM International, D6034-96(2004) Test Method (Analytical Procedure) for Determining the Efficiency of a Production Well in a Confined Aquifer from a Constant Rate Pumping Test

ASTM International, D6391-99(2004) Test Method for Field Measurement of Hydraulic Conductivity Limits of Porous Materials Using Two Stages of Infiltration from a Borehole

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/60/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-08-05

WELL INTEGRITY INSPECTION, MAINTENANCE, AND REHABILITATION
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for inspecting groundwater monitoring well integrity. The well integrity inspection identifies wells that in their current condition are not suitable for obtaining groundwater/product elevations, water quality and/or hydraulic information, groundwater/product samples and/or other data obtained using the well. The results of the evaluation shall be used to ensure the integrity of wells over extended periods of time by identifying conditions that warrant well maintenance and/or rehabilitation. This SOP also describes well maintenance and rehabilitation.

2.0 EQUIPMENT AND MATERIALS

- Map of well locations;
- Tools and well keys, as required to facilitate access to wells;
- Water level measuring device (electronic water level indicator, interface probe, or weighted steel tape);
- Adjustable rate pump, adjustable rate submersible or positive displacement bladder pump (Note: The Site-Specific Work and/or Field Sampling Plan (FSP) shall specify the type of pump required);
- 1/4 to 3/8-inch Teflon®, polyvinyl chloride (PVC), or polypropylene tubing, if applicable;
- Power source, if applicable;
- Compressed inert gas source (for use with bladder pump), if applicable;
- PVC or stainless steel bailer or solid slug;
- Rope;
- Pressure transducer and automatic data logger, if applicable;
- Container(s) for purge water storage (e.g. 5-gallon buckets, polyethylene storage tank, etc.);
- Existing well boring/construction logs, if available;
- Groundwater elevation table, if available;
- Polyethylene sheeting, as appropriate;

- Camera;
- Personal protection equipment; and
- Field logbook and/or appropriate field forms.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 EXECUTION

Inspections shall be performed at the frequencies described below or as required by the Site-Specific Work Plan to 1) verify the structural integrity of the wells above and below ground, 2) identify significant silt/sediment buildup in wells, and 3) identify biofouling that could contribute to corrosion of structures or decrease in the efficiency of recovery and pumping operations.

4.1 Well Location Verification

The location of each well shall be compared to that given on the site map. If the well location is found to be in error, the well shall be resurveyed and/or re-delineated relative to site features and its position adjusted on the map.

4.2 Aboveground Structural Integrity Inspection

The physical condition of the well will be determined by visually inspecting aboveground components during each monitoring and/or sampling event. Components to be inspected include:

- Protective casing/flush-mount cover;
- Bumper posts, if applicable;
- Concrete pad or apron, if applicable;
- Well cap (expandable or slip);
- Locking mechanism;
- Exposed top of casing; and
- Surface drainage around the wells.

If the aboveground components are damaged, well maintenance or rehabilitation is required (see Section 4.3).

4.3 Below Ground Well Structural Integrity Inspection

4.3.1 General

Total depth measurements shall be obtained annually in accordance with SOP ENV-08-01 and compared to the baseline total depth measurements obtained at the time of well installation, development, and/or start of the project. If a significant amount of silt/sediment is present, well maintenance or rehabilitation is required (see Section 4.4). Additionally, single well aquifer testing may be performed to determine if silt/sediment has decreased the well hydraulic conductivity, indicating well maintenance or rehabilitation is necessary for collection of representative data. Use of this test will be determined on a site-specific basis or as otherwise determine in the SSWPs.

4.3.2 Monitoring Wells

A stainless steel or PVC bailer or slug, with a diameter and length equivalent to a sampling pump or bailer, shall be lowered the entire length of the well to identify obstructions or damage to the well casing and screen. If the bailer or slug cannot be lowered to within the screened interval, an obstruction or damage exists that requires well maintenance or rehabilitation (see Section 4.4). If well yield decreases significantly, well integrity may be assessed using a single well aquifer test to determine if well maintenance or rehabilitation is required.

4.3.3 Vapor Extraction Wells

Vacuum and air flow rates shall be measured periodically in accordance with system-specific procedures and compared to previous steady-state measurements and the current operational status of the system. If a significant change in vacuum and/or air flow rates is observed and not substantiated by the current operational status of the system, well maintenance or rehabilitation is required (see Section 4.4).

4.3.4 Recovery Wells

Recovery rates shall be evaluated at least once every quarter and compared to previous measurements. If a significant change in rates is observed and not substantiated by current product/water levels, well maintenance or rehabilitation is required (see Section 4.4).

4.4 Well Maintenance or Rehabilitation

Deficiencies or damage identified during aboveground and below ground well integrity inspections shall be evaluated on a case-by-case basis. Well maintenance or rehabilitation that cannot be implemented at the time of inspection shall be implemented within a reasonable period of time. Well maintenance or rehabilitation may include, but is not limited to, the following:

- Replacement of aboveground components;
- Silt/sediment removal;
- Well surging and redevelopment;
- Biomass removal and/or cleaning with an approved biocide; and
- Equipment (e.g. pumps, etc.) repair or replacement.

If deficiency or damage cannot be corrected through well maintenance or rehabilitation, the well shall be abandoned in accordance with SOP ENV-05-05 and applicable federal, state, and local regulations. Wells critical to site activities and/or operations shall be replaced in accordance with SOPs ENV-05-03 and ENV-05-04, applicable federal, state, and local regulations, and the Site-Specific Work Plan.

4.5 Decontamination

Non-Dedicated and dedicated equipment used for inspection and/or corrective action activities, which does not remain within the well casing, shall be removed from the well. The reusable and/or dedicated equipment and instruments shall be decontaminated in accordance with SOP ENV-04-04 or as otherwise specified by the Site-Specific Work Plan. Disposable equipment and supplies shall be disposed of in accordance with procedures outlined in the Site-Specific Work Plan.

5.0 DOCUMENTATION

Inspection, maintenance, and rehabilitation activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as otherwise required by the Site-Specific Work Plan.

6.0 REFERENCES AND ADDITIONAL RESOURCES

ASTM International, D6089-97(2003) Standard Guide for Documenting a Ground-Water Sampling Event

ASTM International, D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells

USEPA, 2001, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), Region 4, Enforcement and Investigations Branch, SESD, Athens, Georgia, www.epa.gov/region4/sesd/eisopqam/eisopqam.html.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-09

SURFACE WATER SAMPLING AND MEASUREMENT PROCEDURES

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STANDARD OPERATING PROCEDURE NO. SAS-09-01

SURFACE WATER SAMPLING FOR CHEMICAL AND BIOLOGICAL ANALYSIS Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for the collection of grab surface water samples for chemical and biological analysis using manual sampling techniques. The collection of composite surface water samples using automatic samplers shall be address in an equipment-specific SOP or the Site-Specific Work Plan, as needed. Surface water samples are utilized for the characterization of surface water and assessment of human and ecological receptors.

2.0 EQUIPMENT AND MATERIALS

Sampling equipment and materials vary by collection method. However, some standard equipment and materials are required regardless of collection method:

- Hip or chest waders, as appropriate;
- Boat and personal floatation devices (PFDs), as needed;
- Sample bottles/containers and labels;
- Field logbook and/or the appropriate field form(s);
- Pens with waterproof, non-erasable ink;
- Chain of custody forms;
- Depth and length measurement devices;
- Survey stakes, flags, or buoys and anchors;
- Decontamination materials;
- Coolers and ice packs/double-bagged ice;
- Personal protective equipment; and
- Camera.

3.0 HEALTH AND SAFETY WARNINGS

Aquatic environments present unique health and safety concerns ranging from accessibility to water depth and velocity to indigenous species. Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 PERMITTING

Sampling performed within navigable waters and critical habitats may fall under the jurisdiction of one or more federal, state, or local agencies, including by not limited to the United States Army Corp of Engineers (USACOE), US Department of Fish and Wildlife, and State Departments of Natural Resources. Prior to the commencement of sampling activities, appropriate permit(s), if applicable, shall be obtained.

5.0 EXECUTION

5.1 General Considerations

The scope or extent of the sampling effort, data quality objectives, type(s) of samples (e.g. surface or depth grab), and sampling technique shall be determined prior to sample site selection and sample collection. In addition, the hydrology and morphometrics of a stream or impoundment shall be determined to the extent practical prior to sample collection. Water quality data (e.g. dissolved oxygen, pH, and temperature, etc.) shall be collected prior to sample collection, to the extent practical, to determine if stratification is present. These sampling activities should be restricted to seasons when ice is not present, unless specified by a Site-Specific Work Plan and/or Field Sampling Plan (FSP). The Site-Specific Work Plan and/or FSP, as appropriate, shall specify the type(s) of samples to be collected and the collection technique(s).

5.2 Sample Site Selection

An initial reconnaissance shall be performed, to the extent practical, identify suitable sampling locations. Bridges and piers shall generally be deemed acceptable sampling locations since they provide ready access and permit water sampling at any point across the width of the water body. However, data quality objectives (DQOs) must be reviewed prior to final acceptance of these structures as sampling locations, since these structures alter the nature of water flow. When samples will be collected by wading in lakes, ponds, and slow-moving rivers and streams, sampling locations shall be selected that allow the sampler to approach the location from downstream in order to minimize the disturbance of sediments. Sampling station locations shall be selected without regard to other means of access if the stream is navigable by boat. However, other factors including but not limited to the following shall be considered in the sample site selection process:

- Project goals and DQOs;
- Field personnel health and safety;
- Manmade structures that alter the nature of water flow and mixing;
- General water environment characteristics (e.g. flow, depth, stratification, etc.);
- Potential disturbance of threatened or endangered species or critical habitat; and
- Type of water environment: river, streams, creeks; lakes, ponds, impoundments, estuarine, etc.

5.3 Surface Grab Sample Collection Procedures

Surface grab samples shall be collected from the top 12 inches of the water column. Samples shall be collected in a manner that avoids skimming of the surface and disturbance of sediments. If sample collection is performed by wading in the stream, the location shall be approached from a downstream location and efforts shall be made to minimize sediment disturbance, which has the potential to bias the sample. Wading shall be deemed acceptable if a noticeable current is present and the samples can be collected directly into the bottle from a location upstream of the field personnel. The field personnel shall approach the sample location slowly from downstream in order to minimize sediment disruption and sample corruption.

5.3.1 Direct Grab Sampling

Where practical, use of the actual sample container as the collection device is preferred since the same container can be submitted for laboratory analysis. This procedure reduces sample handling and potential loss of analytes or contamination from the sample from other sources. The following procedure shall be used for direct grab sample collection using unpreserved sample containers:

1. Remove the container cap or lid.
2. Slowly submerge the container, opening first, into the water.
3. Invert the container so the opening is upright and pointing towards the direction of water flow (if applicable) and allow water to slowly run into and fill the container.
4. Return the filled container to the surface.
5. If field preservation is required, proceed to Step 6; otherwise, secure the container cap or lid and proceed to Step 10.
6. Pour out a small volume of sample away from and downstream of the sampling location. (Do not use this step for volatile organics or other analytes that require zero headspace.)
7. Add the appropriate volume of the analytical method-prescribed preservative and secure the container cap or lid.
8. Invert the container several times to ensure sufficient mixing of the sample and preservative.
9. Check the preservation of the sample; adjust the pH of the sample with additional preservative, if necessary; and re-secure the cap or lid.
10. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.3.2 Sampling with an Intermediate Vessel or Container

If the sample cannot be collected directly in the sample container(s), an unpreserved sample container or an intermediate vessel (e.g. beaker, bucket, or dipper with or without an extension arm) shall be used to obtain the sample using the following procedure:

1. Decontamination the intermediate vessel in accordance with SOP ENV-04-04 or use certified clean, laboratory provided, unpreserved bottles.
2. Fill the intermediate vessel or container by slowly dipping it into the water with the opening pointing towards the direction of water flow (if applicable);

3. Allow water to slowly run into and fill the intermediate vessel or container in a manner that minimizes agitation of the sample;
4. If field preservation is required, ensure the preservative is present in the sample container prior to transfering water from the intermediate vessel;
5. Remove the sample container lid and fill the sample container(s) from the intermediate vessel or container while avoid direct contact between them;
6. Secure the sample container lid.
7. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.3.3 Sampling with a Pump and Tubing

The following procedure shall be used for the collection of a surface grab sample using a pump and dedicated tubing:

1. Decontaminate the pump in accordance with SOP ENV-04-04, as appropriate.
2. Lower the tubing or pump intake to a depth of 6 to 12 inches below the water surface, where possible. The pump intake or intake tubing shall be maintained below the water surface during sample collection.
3. Pump several tubing volumes through the system prior to collecting the first sample.
4. If field preservation is required, ensure the preservative is present in the sample container prior to filling the sample container;
5. Fill the sample container(s) from the discharge tubing.
6. Secure the sample container lid.
7. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.4 Depth Grab Sample Collection Procedures

Depth grab samples shall be collected from at least below the top 12 inches of the water column to within 6 inches of the stream or impoundment bed, at depths to satisfy the DQOs specified by a Site-Specific Work Plan and/or determined in the field based on field encountered conditions (i.e., stratification, water column depth, etc.). Specific sample collection procedures for depth grab samples are presented below. If sample collection is performed by wading in the stream, the location shall be approached from a downstream location and efforts made to minimize sediment disturbance, which has the potential to bias the sample. Wading shall be deemed acceptable if a noticeable current is present and the samples can be collected from a location upstream of the field personnel. The field personnel shall approach the sample location slowly from downstream in order to minimize sediment disruption and sample corruption.

5.4.1 Sampling with Kemmerer, Niskin, or Van Dorn Type Devices

To the extent practical, devices constructed of stainless steel or Teflon or with Teflon-coated surfaces shall be used. Samplers that are constructed of plastic and rubber shall not be used to collect samples for extractable organics or volatile organic compound (VOC) analysis. The following procedure shall be used to collect depth grab samples using these devices:

1. Decontaminate the device in accordance with SOP ENV-04-04;
2. Measure the water column to determine the maximum depth and sampling depths;
3. Mark the line attached to the device with depth increments so that the sampling depth can be accurately recorded;
4. Slowly lower the device to the desired sampling depth in a manner that minimizes sediment disturbance;
5. At the desired depth, send the messenger weight down to trip the closure mechanism;
6. Slowly retrieve the device;
7. Rinse the outside of the device with distilled water;
8. Remove the sample container cap or lid and fill the container via the discharge tube;
9. If field preservation is required, follow Step 6 through Step 9 in Section 5.3.1 above; otherwise, proceed to Step 10 below.
10. Secure the sample container lid.
11. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.4.2 Sampling with Double Check-Valve Bailers

If DQOs do not necessitate a sample from a strictly discrete interval of the water column, a double check-valve bailer may be used. The following procedure shall be used to collect a depth grab sample with a double check-valve bailer:

1. Decontaminate the bailer in accordance with SOP ENV-04-04, or use a clean disposable bailer at each sampling location.
2. Measure the water column to determine the maximum depth and sampling depths.
3. Mark the line attached to the bailer with depth increments so that the sampling depth can be recorded.
4. Slowly lower the bailer to the desired sampling depth in a manner that minimize sediment disturbance.
5. Slowly retrieve the bailer.
6. Rinse the outside of the bailer with distilled water.
7. Remove the sample container cap or lid and fill the containers via the discharge port.
8. If field preservation is required, follow Step 6 through Step 9 in Section 5.3.1 above; otherwise, proceed to Step #9 below.
9. Secure the sample container lid.
10. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.4.3 Sampling with a Pump and Tubing

The following procedure shall be used for the collection of a depth grab sample using a pump and dedicated tubing:

1. Decontaminate the pump in accordance with SOP ENV-04-04, as appropriate.
2. Measure the water column to determine the maximum depth and sampling depths.
3. Secure the pump intake or intake tubing to a stiff pole or weight.
4. Lower the pump intake or intake tubing to the desire sample depth.
5. Pump several tubing volumes through the system prior to collecting the first sample.
6. Remove the sample container cap or lid and fill the sample container from the discharge tubing.
7. If field preservation is required, follow Step 6 through Step 9 in Section 5.3.1 above; otherwise, proceed to Step 8 below;
8. Secure the sample container lid.
9. Label the sample container in accordance with SOP ENV-03-01 and place in cooler with double-bagged ice for in preparation for transportation to the analytical laboratory.

5.5 Sampling for Biological Analysis

When sampling for biological or bacteriological examination, the procedures described above shall be followed with one exception, unless otherwise specified in the Site-Specific Work and/or FSP. Samples shall be collected in bottles properly sterilized and protected against contamination. As with any sample collection procedure, while the bottle is open, both the bottle and stopper shall be protected against contamination from other sources and the bottle closed at once following sample collection.

6.0 DOCUMENTATION

Sample information, labeling, and custody control shall be performed in accordance with requirements specified in SOP ENV-03-01 and ENV-03-02. Sampling activities shall be recorded in the field logbook and/or on the appropriate field form as specified in SOP ENV-01-01 or as required by the Site-Specific Work and/or FSP.

7.0 REFERENCES

ASTM International, D3977-97 (2002), Standard Test Methods for Determining Sediment Concentration in Water Samples.

ASTM International, D4581-86 (2005), Guide for Measurement of Morphologic Characteristics of Surface Water Bodies.

ASTM International, D5073-02, Practice for Depth Measurement of Surface Water.

Florida Department of Environmental Protection, February 2004, DEP-SOP-001/01 FS 2100 Surface Water Sampling.

USEPA, November 1994, SOP 2013: Surface Water Sampling, Rev. 0.0, Environmental Response Team.

USEPA, July 2002. Standard Operating Procedures for the Collection of Chemical and Biological Ambient Water Samples. Revision 1.

USEPA. 40 CFR Part 136.3 (e) Table II

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

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STANDARD OPERATING PROCEDURE
NO. SAS-09-02

STREAMFLOW MEASUREMENT
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes guidelines for the calculation of velocity and stream discharge measurements in rivers and streams. Procedures are given for measurements that can be conducted from water vessels (i.e. boats or barges), bridges (if traversing a representatives section of the river) or by wading with assistance from other field personnel working from the stream bank.

2.0 EQUIPMENT AND MATERIALS

- Flow Meter;
- Top-setting wading rod (measured in tenths of a foot);
- Tape measure or tagline (long enough to traverse the stream bed)
- Stakes to anchor tape to shore;
- Mallet or hammer;
- Field logbook and applicable field data sheets;
- Pen(s) with waterproof, non-erasable ink;
- Waders; and
- Personal protective equipment.

3.0 HEALTH AND SAFETY WARNINGS

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Work on water requires that marine health and safety procedures are used in addition to standard health and safety procedures. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 GENERAL PROCEDURES

4.1 Standard Field Procedures

Streamflow measurements shall be conducted only by a trained technician. Field data and observations associated with streamflow measurements shall be documented in accordance with SOP ENV-01-01, if not otherwise specified in this SOP. All activities should be recorded in a field logbook and/or on a streamflow measurement field form.

4.2 Site Selection

The stream transect location is a critical component of streamflow measurement. A site where the stream is most consistent in depth and flow rate across its width is easier to sample and provides more accurate results. Flow sites should be free of eddies, slack water, and excessive turbulence. Avoid areas where islands, ox-bows, piles of debris, aquatic plants or tributaries are present.

4.3 Flow Meter Selection

Several flow meters are available for measuring stream velocity. Some specific meters are the Price Model #1210 (AA); Price Model #1205 (Pygmy) for small, shallow streams; the March-McBirney 201D; and the March-McBirney Flo-Mate 2000. Selection of an appropriate flow meter will depend on the width and depth of the stream being measured, as well as stream features and irregularities. Additional guidance for selection of flow meters may be given in the Site-specific Work Plan.

4.4 Calculation of Stream Discharge

Stream discharge is determined by multiplying the mean stream velocity by the cross sectional area of the flow. The general form of the discharge equation is:

$$Q = A \text{ x } v$$

Where: Q = discharge in cubic feet per second (cfs)
A = cross section area of the channel at the transect in square feet (ft^2)
v = mean water column velocity at the transect in feet per second (ft/s)

To measure discharge (Q), a transect of the stream is divided into subsections and velocity, width and depth measurements are made within each subsection. Discharge of the stream at the transect is calculated by a form of the general equation:

$$Q = \sum_{i=1}^{n} (A_i \, x \, v_i)$$

Where: Q = discharge (cfs)
A_i = cross-sectional area of subsection I (ft^2)
v_i = velocity of subsection (ft/s)

A variation of this equation for mid-section method from Rantz (1982) is presented is Section 7.0 below. Other variations can be found in references listed at the end of this SOP and may be used as specified in the Site-specific Work Plan.

5.0 FIELD MEASUREMENT PROCEDURES

1. Calibrate the flow meter as specified in the manufacturer's instructions.
2. Attach the flow meter to the top set wading rod.
3. Measure the width of the stream at the selected transect location is measured by staking one end of the tape measure or pre-measured and incrementally marked tagline on the right bank. Pull the tape measure across the stream keeping it perpendicular to the flow and stake it on the left bank or use GPS to establish a transect location if sampling from a vessel. Measure the width of the stream from left edge of water (LEW) to right edge of water (REW). LEW is defined as the point where water flow begins on the transect as you face downstream. REW is where water flows ends on the transect.

4. Determine the spacing of transect subsections to be used for velocity measurements. Each subsection should have a width of 5% to 10% of the stream width. For an accurate measurement of discharge, velocity should be measured in 20 to 30 subsections. If inconsistencies in flow rate or streambed topography are present, the number and sizes of subsections can be adjusted to accommodate the differences. Additional guidance on subdividing the transect may be given in the Site-specific Work Plan.
5. Determine the mid-point of each subsection. Use a cumulative measurement. If the stream is 30 feet wide with 20 subsections, the first mid-point is located at 0.75 feet from LEW, the second is located at 2.25 feet from LEW, etc. Draw a rough sketch of the transect with subsections and mid-point measurements in the field logbook and/or on the appropriate field form.
6. Begin the velocity and depth measurements at the first subsection mid-point as measured from the LEW. Measure the total depth of water using the scale on the lower portion of the wading rod or 2-inch diameter graduated aluminum pole. Single indentations on the rod indicate 0.1 foot, double indentations indicate 0.5 foot and triple indentations indicate 1.0 foot. Depending on water depths, velocity measurements will be taken at one or two depths as follows:
   - Depths ≤ 2.5 feet – one measurement is taken at 60% of the total depth when measured from the surface of the water. To set the sensor of the flow meter at 60% of the depth, line up the foot scale on the sliding rod with the tenth scale on the top of the depth gauge rod. For example, if the first subsection is 1.5 feet deep, line up the 1 foot indentation on the sliding rod with the 5 on the tenth scale on the depth gauge rod.
   - Depths > 2.5 feet – two measurements are taken: one at 20% of the total depth and one at 80% of the total depth when measured from the surface of the water. To set the 20% depth point, multiply the depth of the water by two and move the sliding rod so that the foot measurement on it lines up with the tenth of a foot measure on the depth gauge rod. For example, if the first subsection is 2.8 feet deep, twice the depth is 5.6 feet. Line up the number 5 on the sliding rod with the 6 on the depth gauge rod. To set the 80% depth point, divide the depth of the water by two and move the sliding rod to line up with the depth gauge rod based on the results. For example, 2.8 feet divided by 2 equals 1.4 feet. Line up the number 1 on the sliding rod with the 4 on the depth gauge rod. The average of the two velocity measurements are used in the flow calculation.

Take the velocity measurement(s) following the manufacturer's instructions and record them in the field logbook or on the field log form. Proceed to the next subsection of the transect and repeat the procedure across the stream towards the REW.

7. If required, continue to next transect location and repeat the measurement procedures.

6.0 DISCHARGE CALCULATIONS

Calculate the discharge in each transect subsection by multiplying the average velocity (>2.5-foot depth subsection) or single velocity (≤ 2.5-foot depth) by the subsection width and average depth using the equation:

$$Q = \left(\frac{D_1 + D_2}{2}\right)\left(\frac{v_1 + v_2}{2}\right)W_1 + \ldots + \left(\frac{D_m + D_n}{2}\right)\left(\frac{v_m + v_n}{2}\right)W_m$$

Where: Q = discharge (cfs)
v = velocity of subsection (ft/s)
W = width of subsection (ft)

Note: The first and last subsections are located at the edges of the stream and have a depth and velocity of zero (D_1, D_n, v_1 and v_n).

7.0 QUALITY ASSURANCE/QUALITY CONTROL

7.1 Equipment Calibration, Operation, and Maintenance

All field equipment shall be calibrated, operated, and maintained in accordance with SOP ENV-02-01 and manufacturer's instructions.

7.2 Calculations

All calculations shall be checked by another person for correctness and use of appropriate equations. Any corrections required will be made by the person originally performing the calculations. These corrections will be checked for correctness and approved for publication.

8.0 REFERENCES AND ADDITIONAL RESOURCES

Carter, R. W. and Davidian, J., 1969, General Procedure for Gaging Streams: Techniques of Water Resources Investigations of the U.S. Geological Survey, Book 3.

California Department of Pesticide Regulation, Environmental Monitoring Branch, 2004, Standard Operating Procedure for Determining Wadable Stream Discharge with Price Current Meters, SOP Number: FSWA009.01.

Rantz, S.E., 1982, *Measurement and Computation of Streamflow: Volumes 1 and 2*, "Measurement of Stage and Discharge", U.S. Geological Survey Water-Supply Paper 2175.

Florida Department of Environmental Protection, Bureau of Watershed Management, Watershed Assessment Section, February 2004, FT 1800 Field Measurement of Water Flow and Velocity. DEP-SOP-001/01.

USEPA, Region 6, January 2003, Standard Operating Procedure for Streamflow Measurement.

USEPA, April 2007, Guidance for Preparing Standard Operating Procedures (SOPs), EPA/600/B-07/001.

SOP SERIES SAS-11

SOIL VAPOR SAMPLING AND MEASUREMENT PROCEDURES

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STANDARD OPERATING PROCEDURE NO. SAS-11-01

SUB-SLAB SAMPLE PORT INSTALLATION, SAMPLING, AND ABANDONMENT Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the guidelines for installation and sampling of sub-slab sample ports. Soil gas sampling is a useful tool to evaluate the potential for vapor intrusion at sites with subsurface chemical impacts and existing buildings. Sub-slab sampling is conducted directly beneath the building's slab to provide measurements of soil gas that may potentially enter a building.

2.0 EQUIPMENT AND MATERIALS

- Rotary hammer drill (or equivalent) with 1-inch and 5/16-inch diameter bits;
- Hand tools, including a hammer, needle-nose pliers, and trowel;
- "T" Swagelok® (compression) or equivalent fitting;
- 3-way and 2-way stopcocks;
- ¼-inch O.D. Teflon™ tubing;
- Tedlar™ bags;
- Plastic helium shroud;
- Broom and dust pan or hand vacuum;
- Beeswax;
- Nitrile gloves;
- Summa™ canisters with flow controllers, particulate filters, vacuum gauges, and shipping container;
- Sample labels;
- Chain of custody forms and seals;
- Field air monitoring instruments, as specified in the Work Plan (e.g. photoionization detector (PID), multi-gas monitors, etc.)
- Location markers (e.g. pin flags, wooden stakes, flagging tape, etc.);

- Asphalt cold patch or cement, as appropriate for site restoration; and
- Field logbook and/or appropriate field forms

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Variations in chemical-specific characteristics, geologic conditions, and atmospheric influences can affect soil-gas sampling results. For this reason, it is important to understand factors the may influence the reported data when collecting soil-gas data. In all cases, site-specific factors should be carefully evaluated prior to initiation of sampling to obtain representative soil-gas data.

Prior to any soil-gas sampling, soil type must be evaluated for suitability of sampling. Soils with smaller grain sizes have smaller pore spaces and are less permeable, which may reduce the ability for soil gas to be released from the subsurface. For example, clays have the smallest grain size and significantly restrict soil gas migration. Soil moisture also limits the ability for soil gas to be released from the subsurface because moisture trapped in the pore space of sediments can inhibit or block soil-gas flow. Seasonal and geographical variations in soil moisture content can affect air permeabilities. In addition, manmade and naturally occurring preferential pathways (e.g. utility corridors, lenses of coarse-grained materials within fine-grained materials, etc.) may also affect soil-gas migration and shall be considered prior to soil-gas sampling.

Reliability of soil-gas sampling may be improved by using fixed probes and by ensuring that leakage of atmospheric air into the samples is avoided during purging or sampling. To avoid dilution of the sampling region from leakage, the minimum purge volume deemed adequate to flush the sampling system should be removed, and soil-gas samples should be collected from the most permeable zones in the vadose zone when possible. Site-specific information concerning soil lithology, grain size analysis, soil moisture, and soil-gas permeability may be obtained by performing three soil borings in the immediate area of the sampling locations in advance of the soil-gas sampling. In addition, previous site investigation sample results, when available, should be used to determine the placement of the soil-gas sampling locations.

Since oxygen, carbon dioxide, and nitrogen can be sampled using a multi-gas monitor to give real-time results, parallel analysis of oxygen, carbon dioxide, and nitrogen in soil-gas may also be used to help assess the reliability of a given sample result.

5.0 EXECUTION

The active soil-gas sampling approach consists of withdrawing an aliquot of soil gas from the subsurface, followed by the analysis of the withdrawn gas. Active soil-gas systems use mechanical equipment to create a small-diameter hole in the ground and then use a vacuum to "actively" withdraw a soil gas sample through Teflon tubing within the vadose zone. The soil gas sample is collected in a Summa canister and sent to a laboratory for analysis. Samples are analyzed using USEPA's Ambient Air Compendium Method TO-15 (USEPA, 1999) for determining organic compounds in ambient air. The results provided by active soil-gas systems are quantitative and are reported in units of concentration per volume (micrograms per cubic meter [$\mu g/m^3$], or parts per billion volume [ppb_v]).

The following active soil-gas sampling methodologies (port installation and sampling) are based on established methods as outlined in the *USEPA Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)* (USEPA, 2002) and the ASTM International (ASTM) standard guide D 5314-01 (ASTM, 2001). Additional guidelines were provided from the San Diego County Site Assessment and Mitigation (SAM) Manual, "Overview of Soil Vapor Survey Methods" (San Diego County, 2002 and 2004) and the California Regional Water Quality

Control Board (CRWQCB), Los Angeles Region (LARWQCB) (CRWQCB, 2002 and 2003) and the Department of Toxic Substances Control (DTSC) guidelines (DTSC, 2004).

5.1 PRE-SAMPLING ACTIVITIES

Before starting field activities, attempts should be made to obtain as-built drawings for each building to determine foundation thickness and utility locations. The as-built drawings should be used to finalize probe placement in each of the buildings.

Prior to installing the sub-slab vapor probes, a building survey will be completed. The purpose of the building survey is to document general building structural and use information, including describing the general building uses, presence/absence of wells or sumps, presence/absence of a basement, and documenting potential indoor VOC sources by identifying what chemicals are used or are present in the building. Rooms where probes are proposed should be screened with a PID. If available, Material Safety Data Sheets (MSDSs) for products used in the building will be obtained. The initial building survey will also include identifying the points at which subsurface utilities enter the building. A Building Questionnaire (See Attachments) form should be used for the initial building survey.

5.2 SUB-SLAB SOIL VAPOR PROBE CONSTRUCTION AND INSTALLATION

The sub-slab soil vapor probe installation procedures were derived primarily from the USEPA's *Draft Standard Operating Procedure for Installation of Sub-Slab Vapor Probes and Sampling Using EPA Method TO-15 to Support Vapor Intrusion Investigations* (USEPA, 2002). The sub-slab probes described in the USEPA SOP and in the following procedures are permanent sampling probes that will remain in place after completion of the sampling event. Permanent sampling probes are preferred because they provide higher quality and more consistent data. The individual probes will be removed and the holes sealed upon determining that further sub-slab soil vapor sampling will not be required at a given location.

Use a rotary hammer drill and a clean drill bit to create a shallow (2.5 centimeters (cm) or 1 inch) outer hole that partially penetrates the slab. Areas of visible staining or known previous chemical spills will be avoided. Use a small brush and dust pan or hand vacuum to collect concrete dust and cuttings from the hole. Since the outer hole does not penetrate the floor slab, a dedicated drill bit is not required.

After completing the outer hole, a rotary hammer drill will be used to create a smaller diameter inner hole (0.8 cm or 5/16 inch) through the remainder of the slab and approximately 7 to 8 cm or 3 inches into sub-slab material. The inner hole should be drilled using a dedicated drill bit. Drilling into sub-slab material will create an open cavity which will prevent obstruction of probe inlets during vapor sampling. After completing drilling, the outer hole should be cleaned using a towel moistened with deionized water to increase the potential of obtaining a good seal during cement application.

Probes should be constructed of stainless steel, brass, or Teflon™ tubing and fittings to ensure that construction materials are not a source of VOCs. Metal probe materials should be cleaned with detergent and water prior to installation to remove cutting oils that may have been used in manufacturing. Once the thickness of the slab is known, stainless steel or Teflon™ tubing should be cut to ensure that probes “float” in the slab to avoid obstruction of the probe with sub-slab material. Construct sub-slab vapor probes from small diameter (0.64 cm or 1/4 inch outer diameter x 0.46 cm or 0.18 inch inner diameter) chromatography grade 316 stainless steel or brass tubing and stainless-steel or brass compression to thread fittings (e.g., 0.64 cm or 1/4 inch outer diameter x 0.32 cm or 1/8 inch NPT (National Pipe Tapered) Swagelok® female thread connectors). The probes will be closed using 0.32 cm (1/8 inch) recessed stainless steel or brass socket plugs.

Set sub-slab vapor probes in holes such that the fittings rest at the base of the outer hole and the top of the probes are completed flush with the slab. Each probe will have recessed stainless steel or brass plugs so as not to interfere with day-to-day use of buildings. Mix a quick-drying portland cement that expands upon drying (to ensure a tight seal) with deionized water to form a slurry and inject or push into the annular space between the probe and outside of the outer hole. Allow cement to cure for at least 24 hours prior to sampling.

5.3 SUB-SLAB SAMPLING PROCEDURES

Subsurface vapor will not be sampled if measurable precipitation or irrigation near the sampling location has occurred within the previous five days. The increased soil moisture can reduce soil permeability and cause the soil vapor sample results to be biased low.

5.3.1 Sample Train Assembly

Samples will be collected from the previously installed soil vapor probes using evacuated batch-certified 1 liter (L) or smaller Summa™ canisters equipped with dedicated flow regulators and integrated particulate filters. A flow regulator/particulate filter and vacuum gauge will be attached to each canister as described in the Summa Canister Instructions provided by the laboratory. Canisters, flow regulators/particulate filters, and vacuum gauges will be supplied by the laboratory.

A helium shroud, consisting of a solid plastic container with a height of less than 6 inches and a volume less than 6L, will be placed around the exposed portion of the soil vapor probe. A dedicated stainless-steel fitting and Teflon™ tubing will be connected to the soil vapor probe while passing through a ¼-inch hole in the side of the helium shroud, no more than three inches above the base of the shroud. All fittings and tubing will be dedicated in order to avoid cross-contamination between probes. A second length of Teflon™ tubing will be inserted into the side of the shroud and connected to a helium cylinder on the outside of the shroud. The Teflon™ tubing attached to the soil vapor probe will be connected to a two-way stopcock. The two-way stopcock will be attached to a three-way stopcock. The other two outlets on the three-way stopcock will be attached to Teflon™ tubing. The tubing from one outlet of the three-way stopcock will be connected to the Summa™ canister assembly, and the tubing from the other outlet will be connected to a 1L Tedlar™ (or equivalent) bag. The Tedlar™ bag will be placed in a lung box. An air pump will be used to evacuate the air inside the lung box and collect a sub-slab soil gas sample in the 1L Tedlar™ bag. A new pair of Nitrile gloves should be worn while connecting the sample assembly for each soil vapor probe. The total length of Teflon™ tubing should not exceed 5 feet.

When collecting duplicate or QA split samples, two separate canister assemblies are connected using a stainless steel “T” fitting, and the “T” fitting is then connected to the three-way stopcock using Teflon™ tubing. The “T” fitting will be provided by the laboratory.

5.3.2 Helium Leak Testing

The purpose of the chemical leak test is to ensure that the sub slab sample port and probe assembly is properly set and not leaking. A leaking sub slab probe assembly could result in a leakage of indoor air into the sub slab sample, potentially biasing the sample. Prior to sampling, a chemical leak test will be performed using helium as a tracer gas. The ambient air inside the shroud will be replaced with helium graded at 99.9 percent purity or higher until the atmosphere consists of a minimum of 20 percent helium. It should be noted that concentrations of 60 percent to 80 percent helium have routinely been observed in the shroud during prior field testing. This will be accomplished by inserting Teflon™ tubing through a ¼ inch hole in the shroud and attaching the other end to the helium canister. The helium canister will then be opened, and the shroud atmosphere will be continuously monitored by a Dielectric Technologies Model MGD-2002 Multi-Gas Detector (or equivalent) until the percentage of helium inside the shroud reaches a minimum of 20 percent and the readings on the Multi-Gas Detector (or equivalent) stop increasing. The final helium concentration inside the shroud will be recorded on the Field Data Air Sampling Form. The final helium concentration inside the shroud will be multiplied by 10 percent (0.1) to determine the allowable concentration of helium in the Tedlar™ bag sample. Both the final helium concentration inside the shroud and the calculated allowable concentration in the Tedlar™ bag will be recorded on the Field Data Air Sampling Form (See Attachments).

After the target atmosphere is established, the two-way and three-way stopcocks will be opened to the lung box, which contains a 1 L Tedlar™ bag. An air pump attached to the lung box via Teflon™ tubing will be used to evacuate the existing air inside the lung box, which will in turn cause the 1 L Tedlar™ bag to fill. Once filled, the 1 L Tedlar™ bag will be removed from the lung box and the air inside will be measured using the Model MGD-2002 Multi-Gas Detector (or equivalent) for the presence of helium. The concentration of helium measured inside the Tedlar™ bag will be recorded on the Field Data Air Sampling Form. If the concentration of helium in the sample is below the calculated allowable concentration (i.e., less than 10 percent of the concentration inside the helium shroud), proceed with the mechanical leak test and sample collection as described in Sections 5.3.3 and 5.3.4.

Corrective actions to mitigate leaks in the sub-slab soil vapor probe will be performed when the helium concentration in the Tedlar™ bag sample exceeds 10 percent of the starting concentration in the helium shroud. Corrective actions will be performed in the field and will initially involve resealing the probe base with beeswax and repeating the helium leak test. If resealing and retesting fails to produce acceptable leak test results after two attempts, the probe will be abandoned and a new probe will be installed. Samples will not be collected for submittal for laboratory analysis when the helium concentration in the Tedlar™ bag sample exceeds 10 percent of the starting helium concentration in the shroud.

5.3.3 Mechanical Leak Testing

The mechanical leak test will be performed immediately after completing the helium leak test. The mechanical leak test will be completed by closing the two-way stopcock and turning the valve on the three-way stopcock to close the tubing connected to the lung box assembly. This will close the connection between the two-way stopcock and the lung box assembly and open the connection between the two-way stopcock and the Summa™ canister. Vacuum test the connections between the Summa™ canister and stopcock by opening the canister valve to place a test vacuum on the assembly for 10 minutes. The start time and initial vacuum, as well as the stop time and final vacuum, will be recorded on the Field Data Air Sampling Form and in the field logbook. If gauge vacuum can not be maintained for 10 minutes, work shall be suspended and all fittings in the sample assembly will be checked. Retest the sample assembly. If vacuum still can not be maintained by 10 minutes, sampling activities will be discontinued until leak can be identified and addressed.

If gauge vacuum was maintained for 10 minutes, close the canister valve and immediately proceed with sample collection as described in Section 5.3.4. Since the fitting that connects the tubing from the sub-slab probe to the two-way stopcock cannot be leak tested through either the helium or mechanical leak tests, this fitting will be sealed with Teflon™ tape and beeswax.

5.3.4 Sample Collection

Sample location information and meteorological conditions (temperature, barometric pressure, wind speed/direction, and relative humidity) shall be recorded on a Field Data Air Sampling Form. Meteorological data will be obtained online from the nearest National Weather Service measuring station. Digital photos will be taken of each sample location and sample assembly.

Open the two-way stopcock connecting the Summa™ canister assembly to the soil vapor probe. Open the canister valve to begin sample collection. The time and initial vacuum when sample collection starts shall be recorded on the Field Data Air Sampling Form. The laboratory-provided flow regulators will be calibrated for a 5- to 10-minute sample duration, which correlates to a flow rate of 100 to 200 mL/min. Close the sample canister valve when the vacuum gauge indicates approximately 3-5 inches Hg (mercury) of vacuum remain in the canister. Sample collection should take approximately 5 minutes for a 1L Summa™ canister connected to a 200 mL/min flow regulator. The time sample collection was stopped and final vacuum shall be recorded on the Field Data Air Sampling Form. Remove the flow regulator/particulate filter and vacuum gauge assembly and replace the laboratory-supplied brass plug on the canister. Disconnect the sample tubing assembly and replace the plug on the soil vapor probe.

Label the sample canister and record on the COC the sample name, date and time the sample was collected, the canister and flow controller serial numbers, and the final vacuum gauge reading. Samples shall not be chilled or subjected to extreme temperature or pressure fluctuations. Samples will be shipped to the laboratory for analysis of VOCs by USEPA Method TO-15.

5.3.5 Quality Control

Trip blanks, field duplicates, and QA samples will be collected during soil vapor sampling activities. Field duplicates and QA split samples will be collected at the rate of one duplicate/QA sample per 10 soil vapor samples (i.e., 10 percent). Normally, field duplicates and QA samples are collected from the same location; however, the “T” connectors used to collect duplicate samples can not be used to collect three simultaneous samples. Therefore, the duplicate and QA samples will be collected from separate locations.

A trip blank, consisting of an unopened evacuated canister, will be sent with each shipment of sub-slab vapor samples. Trip blanks can consist of either unopened fully evacuated canisters or canisters that have been fully charged with zero grade air by the laboratory. Since a fully charged canister has no vacuum with which to pull contaminants into the canister, a fully evacuated canister has a better likelihood of capturing potential transit-related contamination. The trip blank will be provided by the laboratory.

6.0 EQUIPMENT DECONTAMINATION PROCEDURES

All decontamination will be performed according to SAS-04-04.

7.0 INVESTIGATION-DERIVED WASTE (IDW)

The sub-slab vapor probe installation and sampling will generate small amounts of solid IDW including concrete dust, gloves, drill bits, and tubing. This material will be bagged and disposed of as a municipal waste in accordance with applicable regulations. No liquid IDW will be generated. Further discussion of IDW can be found in Section 9 of the *Multi-Site Field Sampling Plan, Former Manufactured Gas Plant Sites, Revision 3”, February 20, 2008.*

8.0 REFERENCES

ASTM International, 2001, ASTM Standard D 5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.

California Regional Water Quality Control Board, Los Angeles Region, 2002, General Laboratory Testing Requirements for Petroleum Hydrocarbon Impacted Sites.

California Regional Water Quality Control Board, Los Angeles Region, 1997, Interim Guidance for Active Soil Gas Investigation, Advisory issued January 28, 2003.

Department of Toxic Substance Control-California Environmental Protection Agency, 2004, Interim Final Guidance to the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air, Revised February 7, 2005.

San Diego County, Site Assessment and Mitigation (SAM) Manual, “Overview of Soil Vapor Survey Methods” Final Draft 8/20/2002.

San Diego County, 2004, Site Assessment and Mitigation (SAM) Manual, “Overview of Soil Vapor Survey Methods”.

United States Environmental Protection Agency (USEPA), 2002. *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance).* Office of Solid Waste and Emergency Response. November 29.

USEPA, 1999, Compendium Method TO-15, Determination of Volatile Organic Compounds (VOCs) in Air Collected In Specially-Prepared Canisters and Analyzed By Gas Chromatography/Mass Spectrometry GC/MS) in *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air,* 2nd Ed., EPA Publication 625/R-96/010b.

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STANDARD OPERATING PROCEDURE
NO. SAS-11-06

SOIL GAS SAMPLING
Revision 1

1.0 PURPOSE

This Standard Operating Procedure (SOP) provides information on soil-gas sampling using an active sampling approach to assess the vapor intrusion pathway. Soil gas will be sampled using dedicated gas vapor tips and the associated installation kit or direct-push rig. Soil gas samples will be collected from the unsaturated zone to provide measurements of soil gas that may potentially enter a building.

2.0 EQUIPMENT AND MATERIALS

- Rotary hammer drill (or equivalent) with a 1 3/8-inch diameter bit;
- Retractable gas vapor tip (GVP);
- Expendable GVP replacements;
- Hand Tools, including a hammer, needle-nose pliers, and trowel;
- Tubing receptacle;
- Teflon compression fittings to connect sampling points at “T” connection;
- “T” Swagelok (compression) or equivalent fitting;
- Stainless steel tubing;
- Gas sampling pump capable of extracting 200 milliliters per minute (mL/min);
- 4-way Teflon micro-valve;
- 1/4-inch O.D. Teflon tubing;
- VOC-free caulk;
- Nitrile gloves;
- Summa canisters with flow controllers, vacuum gauge, and shipping container;
- Sample labels;
- Chain of custody forms and seals;

- Field air monitoring instruments, as specified in the Work Plan (e.g. photo ionization detector, multi-gas monitors, etc.);
- Location markers (e.g. pin flags, wooden stakes, flagging tape, etc.);
- Granular bentonite;
- Asphalt cold patch or cement, as appropriate for site restoration;
- Decontamination materials;
- DOT-specified 55-gallon drum; and
- Field logbook and/or appropriate field form(s);

3.0 HEALTH AND SAFETY

Potentially hazardous conditions relating to chemicals under investigation, equipment and tools in use, utility services in investigation areas, or certain work activities may exist on the site. Protocols are established in each site-specific Health & Safety Plan (HASP) based on corporate health and safety policies and manuals, past field experience, specific site conditions, and chemical hazards known or anticipated to be present from available site data. Before site operations begin, all employees, and subcontractor personnel will have read and understood the HASP and all revisions. Before work begins, all site project staff will sign an agreement and acknowledgment form indicating that they have read and fully understood the HASP and their individual responsibilities, and fully agree to abide by the provisions of the HASP.

4.0 CONSIDERATIONS

Variations in chemical-specific characteristics, geologic conditions, and atmospheric influences can affect soil-gas sampling results. For this reason, it is important to understand factors the may influence the reported data when collecting soil-gas data. In all cases, site-specific factors should be carefully evaluated prior to initiation of sampling to obtain representative soil-gas data.

Prior to any soil-gas sampling, soil type must be evaluated for suitability of sampling. Soils with smaller grain sizes have smaller pore spaces and are less permeable, which may reduce the ability for soil gas to be released from the subsurface. For example, clays have the smallest grain size and significantly restrict soil gas migration. Soil moisture also limits the ability for soil gas to be released from the subsurface because moisture trapped in the pore space of sediments can inhibit or block soil-gas flow. Seasonal and geographical variations in soil moisture content can affect air permeabilities. In addition, manmade and naturally occurring preferential pathways (e.g. utility corridors, lenses of coarse-grained materials within fine-grained materials, etc.) may also affect soil-gas migration and shall be considered prior to soil-gas sampling.

Reliability of soil-gas sampling may be improved by using fixed probes and by ensuring that leakage of atmospheric air into the samples is avoided during purging or sampling. To avoid dilution of the sampling region from leakage, the minimum purge volume deemed adequate to flush the sampling system should be removed, and soil-gas samples should be collected from the most permeable zones in the vadose zone when possible. Site-specific information concerning soil lithology, grain size analysis, soil moisture, and soil-gas permeability may be obtained by performing three soil borings in the immediate area of the sampling locations in advance of the soil-gas sampling. In addition, previous site investigation sample results, when available, should be used to determine the placement of the soil-gas sampling locations.

Since oxygen, carbon dioxide, and nitrogen can be sampled using a multi-gas monitor to give real-time results, parallel analysis of oxygen, carbon dioxide, and nitrogen in soil-gas may also be used to help assess the reliability of a given sample result.

5.0 SOIL VAPOR PROBE INSTALLATION

Prior to installation at each soil vapor probe location, the area will be inspected for clearance of existing utility lines and other obstructions near the sample location. The soil vapor probes will then be installed into the ground surface using a hammer drill connected to drive rods or a direct-push rig. Installation using a hammer drill should be used when depths of less than 10 feet are desired. For depths greater than 10 feet, a direct-push rig will more efficiently drive the probe rods. The soil vapor probes consist of a stainless steel drive tip which is connected to a screen with a length between 2 to 6 inches and diameter of at least 1/8-inch but no larger than 1/2-inch. At the top of the screen, a stainless steel hose barb allows for a connection to Teflon™ or stainless steel tubing for purging and sample collection. Soil gas probes installed at depths greater than 10 feet should be constructed with stainless steel tubing for durability and stability. After the probe is driven to the desired depth, the rods will be removed and a filter pack containing sand will be set to within 2 inches above and below the vapor probe. Above the sand filter pack, granular bentonite will be placed and hydrated in two-foot lifts to ground surface. This bentonite will provide an airtight seal between the soil gas probe and the ambient air. Probes should not be installed shallower than two feet below ground surface (bgs). Each probe will be allowed to set for at least 24 hours before sampling takes place.

6.0 SOIL VAPOR SAMPLING PROCEDURES

Subsurface soil vapor will not be sampled if measurable precipitation or irrigation near the sampling location has occurred within the previous five days. The increased soil moisture can decrease soil permeability and cause the soil vapor sample results to be biased low.

6.1 SAMPLE TRAIN ASSEMBLY

Samples will be collected using evacuated batch-certified 1 liter (L) or smaller Summa™ canisters equipped with dedicated flow regulators and integrated particulate filters. A flow regulator/particulate filter and vacuum gauge will be attached to each canister as described in the *Summa Canister Instructions* provided by the laboratory. Canisters, flow regulators/particulate filters, and vacuum gauges will be supplied by the laboratory.

When probe installation is complete, Teflon™ tubing will extend from the probe to the ground surface. The Teflon™ tubing will be connected to a two-way and three-way stopcock assembly. One output of the stopcock assembly will be connected to the Summa™ canister using a Swagelok™ fitting. The other output of the stopcock assembly will be connected to a lung box containing a Tedlar™ bag. Use of dedicated tubing will avoid cross-contamination between probes. A new pair of Nitrile gloves should be worn while connecting the sample assembly for each soil vapor probe.

When collecting duplicate or QA split samples, two separate canister assemblies are connected using a stainless steel “T” fitting, and the “T” fitting is then connected to the Teflon™ tubing assembly described in the previous paragraph. The “T” fitting will be provided by the laboratory.

6.2 PURGING SOIL VAPOR PROBES

Allow the probe to equilibrate for a minimum of 24 hours from the time of installation before initiating purge procedures. Teflon™ tubing coming from the soil vapor probe will be connected to a lung box containing a Tedlar™ bag. The vapor probe will be purged during the chemical leak test by removing a volume of air equal to three times the volume of the sample probe and tubing. Purging will be conducted using a flow rate of 100 to 200 milliliters per minute (mL/min). Given the small volume of the sample probes, purge air can be discharged to the atmosphere.

6.3 HELIUM LEAK TESTING

The purpose of the chemical leak test is to ensure that the sub slab sample port and probe assembly is properly set and not leaking. A leaking probe assembly could result in a leakage of ambient air into the sample, potentially biasing the sample. Prior to sampling, a chemical leak test will be performed using helium as a tracer gas. The ambient air inside the shroud will be replaced with helium graded at 99.9 percent purity or higher until the atmosphere consists of a minimum of 20 percent helium. It should be noted that concentrations of 60 percent to 80 percent helium have routinely been observed in the shroud during prior field testing. This will be accomplished by inserting Teflon™ tubing through a ¼ inch hole in the shroud and attaching the other end to the helium canister. The helium canister will then be opened, and the shroud atmosphere will be continuously monitored by a Dielectric Technologies Model MGD-2002 Multi-Gas Detector (or equivalent) until the percentage of helium inside the shroud reaches a minimum of 20 percent and the readings on the Multi-Gas Detector (or equivalent) stop increasing. The final helium concentration inside the shroud will be recorded on the Field Data Air Sampling Form. The final helium concentration inside the shroud will be multiplied by 10 percent (0.1) to determine the allowable concentration of helium in the Tedlar™ bag sample. Both the final helium concentration inside the shroud and the calculated allowable concentration in the Tedlar™ bag will be recorded on the Field Data Air Sampling Form (See Attachments).

After the target atmosphere is established, the two-way and three-way stopcocks will be opened to the lung box, which contains a 1 L Tedlar™ bag. An air pump attached to the lung box via Teflon™ tubing will be used to evacuate the existing air inside the lung box, which will in turn cause the 1 L Tedlar™ bag to fill. Once filled, the 1 L Tedlar™ bag will be removed from the lung box and the air inside will be measured using the Model MGD-2002 Multi-Gas Detector (or equivalent) for the presence of helium. The concentration of helium measured inside the Tedlar™ bag will be recorded on the Field Data Air Sampling Form. If the concentration of helium in the sample is below the calculated allowable concentration (i.e., less than 10 percent of the concentration inside the helium shroud), proceed with the mechanical leak test and sample collection as described in Sections 6.4 and 6.5.

Corrective actions to mitigate leaks in the sub-slab soil vapor probe will be performed when the helium concentration in the Tedlar™ bag sample exceeds 10 percent of the starting concentration in the helium shroud. Corrective actions will be performed in the field and will initially involve resealing the probe base with beeswax and repeating the helium leak test. If resealing and retesting fails to produce acceptable leak test results after two attempts, the probe will be abandoned and a new probe will be installed. Samples will not be collected for submittal for laboratory analysis when the helium concentration in the Tedlar™ bag sample exceeds 10 percent of the starting helium concentration in the shroud.

6.4 MECHANICAL LEAK TESTING

The mechanical leak test will be performed immediately after completing the helium leak test. The mechanical leak test will be completed by closing the two-way stopcock and turning the valve on the three-way stopcock to close the tubing connected to the lung box assembly. This will close the connection between the two-way stopcock and the lung box assembly and open the connection between the two-way stopcock and the Summa™ canister. Vacuum test the connections between the Summa™ canister and stopcock by opening the canister valve to place a test vacuum on the assembly for 10 minutes. The start time and initial vacuum, as well as the stop time and final vacuum, will be recorded on the Field Data Air Sampling Form and in the field logbook. If gauge vacuum can not be maintained for 10 minutes, work shall be suspended and all fittings in the sample assembly will be checked. Retest the sample assembly. If vacuum still can not be maintained by 10 minutes, sampling activities will be discontinued until leak can be identified and addressed.

If gauge vacuum was maintained for 10 minutes, close the canister valve and immediately proceed with sample collection as described in Section 6.5. Since the fitting that connects the tubing from the sub-slab probe to the two-way stopcock cannot be leak tested through either the helium or mechanical leak tests, this fitting will be sealed with Teflon™ tape and beeswax.

6.5 SAMPLE COLLECTION

Sample location information, meteorological conditions (temperature, barometric pressure, wind speed/direction, and relative humidity), and results of the field screening analysis shall be recorded on a Field

Data Air Sampling Form. Meteorological data will be obtained online from the nearest National Weather Service measuring station. Digital photos will be taken of each sample location and sample assembly.

Open the sample canister valve to begin sample collection. The time and initial vacuum when sample collection starts shall be recorded on the Field Data Air Sampling Form. The laboratory-provided flow regulators will be calibrated for a 5- to 10-minute sample duration, which correlates to a flow rate of 100 to 200 mL/min. Close the sample canister valve when the vacuum gauge indicates approximately 5 inches Hg (mercury) of vacuum remain in the canister. Sample collection should take approximately 5 minutes for a 1L Summa™ canister connected to a 200 mL/min flow regulator. The time sample collection was stopped and final vacuum shall be recorded on the Field Data Air Sampling Form. Remove the flow regulator/particulate filter and vacuum gauge assembly and replace the laboratory-supplied brass plug on the canister. Disconnect the sample tubing assembly and replace the plug on the soil vapor probe.

Label the sample canister and record on the COC the sample name, date and time the sample was collected, the canister and flow controller serial numbers, and the final vacuum gauge reading. Samples shall not be chilled or subjected to extreme temperature or pressure fluctuations. Samples will be shipped for analysis of VOCs by USEPA Method TO-15.

6.6 QUALITY CONTROL

QC samples will be collected during soil vapor sampling activities. Trip blanks and field duplicates will be collected as necessary. Field duplicates will be collected at the rate of one duplicate sample per 20 soil vapor samples.

A trip blank, consisting of an unopened evacuated canister, will be shipped with the sub-slab vapor samples with each sample shipment. Trip blanks can consist of either unopened fully evacuated canisters or canisters that have been fully charged with zero grade air by the laboratory. Since a fully charged canister has no vacuum with which to pull contaminants into the canister, a fully evacuated canister has a better likelihood of capturing potential transit-related contamination. The trip blank will be provided by the laboratory.

7.0 EQUIPMENT DECONTAMINATION PROCEDURES

All decontamination will be performed according to SAS-04-04.

8.0 INVESTIGATION-DERIVED WASTE (IDW)

The vapor probe installation and sampling will generate small amounts of solid IDW including, concrete dust, gloves, and tubing. This material will be bagged and disposed of as a municipal waste in accordance with applicable regulations. No liquid IDW will be generated. Further discussion of IDW can be found in Section 9 of the *Multi-Site Field Sampling Plan, Former Manufactured Gas Plant Sites, Revision 3", February 20, 2008.*